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SKETCH OF THE GEOLOGY AND ORE DEPOSITS OF THE CHERRY CREEK DISTRICT, ARIZONA.

JOHN A. REID.

INTRODUCTION.

A trip to the Cherry Creek mining district of Arizona, taken on mining business during the month of July, 1905, put the writer in possession of a few facts of interest and value, both to those interested in the geology of that region and to those studying the expanding literature of ore deposits. The geological importance of this locality is two-fold: First, from the standpoint of descriptive geology, concerning the structure and the relation of this structure to the physiography of the plateau region of Arizona; and second, from the standpoint of economic geology, concerning the peculiarity of ore deposition. The famous United Verde copper mine at Jerome is only about sixteen miles north of Cherry Creek on the same range, and the deposits of the two places are apparently very similar. The policy of a rigorous exclusion of outsiders is applied at Jerome, hence there is an additional value attached to the study of the Cherry Creek district.

As the title indicates, merely a sketch of the geology will be presented. The minutiæ of the subject must await that time when correlation with adjacent districts can be made, and the geology of all of this portion of Arizona becomes a unit. The aim of this

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paper is at most merely to constitute a single stratum of the future complete series.

LOCATION.

The Cherry Creek mining district is situated in the northern central part of Arizona, in the Black Hills range of mountains. It is twenty-five miles from Prescott in an air line, in a direction approximately N. 85° E. The name is taken from that of a creek flowing through the area, a tributary of the Rio Verde, noted for the large number of wild cherry trees growing along its borders. Cherry Creek has its headwaters a few miles to the west of the small village of Cherry Creek, better known as Cherry Post Office, through which it flows in its general easterly course. The stream is perennial and furnishes the water for the small farming, fruit and cattle-raising interests which support the inhabitants in its vicinity. The district is reached from Prescott, first, by the Prescott and Eastern Railway twenty-one miles to the railroad station of Cherry Creek, or Dewey Post Office, thence by stage eighteen miles to Cherry Creek proper. The United Verde mine lies to the north, as stated; the Globe district is situated one hundred miles southeast.

TOPOGRAPHY.

The mountain region of Arizona occupies a belt of country running diagonally through the state from the northwest to the southeast, bounded on the northeast by the Great Plateaus and on the southwest by the desert region. The mountain region consists of numerous ranges trending parallel to the direction of the belt in which they lie. This belt being somewhat curved, the ranges are not all parallel, but change from almost north-south to nearly east-west, the average course being N. W.-S. E. The Black Hills range, in which both Cherry Creek and Jerome lie, is a little north of the center of the mountain region. The trend of the range is N. 35° W.; the length, as a distant unit, sixty miles; the width roughly eighteen miles. It is the first range to the west of the Great Plateaus in this part of Arizona, being separated from the mesa land by the valley of the Rio Verde. To the westward lies the Agua Fria valley, drained by Agua Fria

Creek, and separating the Black Hills from the Bradshaw range, in the northern part of which lies Prescott. In form, the Black Hills may be divided into two equal parts, separated by a lower narrower portion. The elevation of the two ends is over six thousand feet; the elevation of the middle portion is about five thousand two hundred feet. The Cherry Creek district lies in this low portion of the range, in the eastern part.

From the hill tops near Cherry Post Office, which here form the range summit, there is a truly magnificent view to the eastward. The slopes descend steeply for three thousand feet to the valley of the Rio Verde, across which the red and pink cliffs of the Plateau limestones rise sheer for several thousand feet, and extend north and south as far as the eye can see. Marvine,[1] who crossed this region in 1871, has presented a brief description of its larger geographic and geologic features.

The topography of the district is simple; the elements are not many and are easily distinguished. The highest hills are of the typical mesa form, and are found best developed immediately surrounding Cherry Post Office just above the valley of the Rio Verde. On the extreme east of the district the steep slopes below the flat mesa tops lead down to the low hills belonging to the river valley. To the west the mesa effect becomes obliterated; the hills rise to about the same level but are of rounded forms. Further west, the altitude becomes gradually lower until the range merges into the lowlands. The valleys separating the individual hills are due either to stream action, when they are wide and flaring, or to orogenic movements when they are sharp cut and narrow. The relief of the district, except on the long east slope of the range, is not great, the hill tops seldom rising more than four hundred or five hundred feet above the intervening valleys.

Cherry Creek is the chief stream draining the district. The divide separating its sources from those of the westward flowing streams lies in the western part of the area. In general, all secondary stream courses are at right angles to the range crest, but vary somewhat on account of faulting and differential weathering in the rocks.

[1] Wheeler Survey, Vol. III., 1875, pp. 207–208.

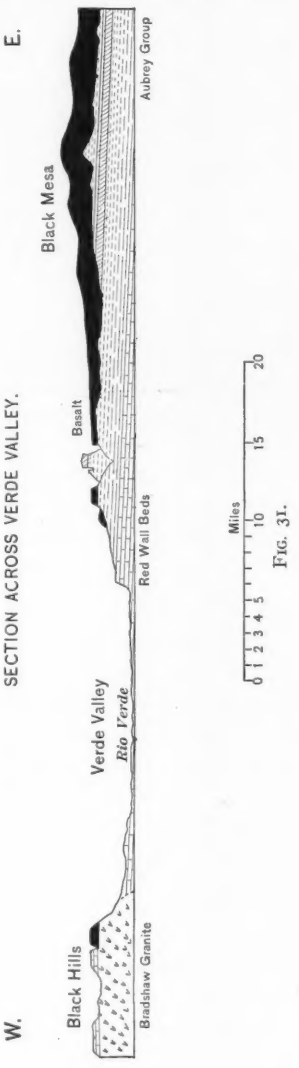
The Black Hills, in this region, furnish fair amounts of timber, although much has been culled, and a sufficient supply of water for mining purposes. At the Pfau mine, on the eastern slope, a water supply sufficient for the needs of a two hundred ton mill and cyanide plant is obtained by pumping from a shallow well.

GENERAL GEOLOGY.

The geology of the district is not complex. Upon the pre-Cambrian complex of schists and granitic rocks rest, in a horizontal or nearly horizontal position, beds of limestone, with a total thickness of approximately one hundred feet. Only isolated patches of this limestone remain, due often to the protecting influence of late basalt, which occurs also in patches as remnants of a series of flows lying nearly or quite horizontal over all other rocks. In the Cherry Creek district, granite, including dikes of granite porphyry, is the only rock of the basement complex, and the younger rocks are found only on the hills along the range crest. It is these later rocks which, both by erosion alone and by erosion after faulting, have produced the mesas of the area. In the extreme west of a section across the Black Hills at Cherry Creek, only a few hundred feet above Agua Fria valley, occur small patches of schist embedded in the granite. To the east, below the steep eastward facing slope of the range, occur other sedimentary beds, largely sandstone, which form a series of low hills and ridges extending out into the valley of the Rio Verde. These eventually join the low hills rising eastward up to the steep escarpment beyond, which forms the western edge of the Great Plateaus. There is roughly a difference in elevation of two thousand feet between the mesa tops near Cherry Creek and the highest of the low hills below the eastern face. The accompanying section, following Marvine[1] for the portion east of the district under discussion, presents graphically the main geological features (Fig. 31). The cliffs to the east of the Rio Verde are formed by the Red Wall series, with the Aubrey beds outcropping further east. Marvine[2] notes that the Rio Verde flows over Red

[1] Wheeler Survey, Part III., p. 226.
[2] Wheeler Survey, Part III., p. 208.

Wall limestone, hence it is probable that the low hills which persist to the east face of the Black Hills belong to the Red Wall beds, above the limestone. These beds dip slightly to the east toward the river. At the Pfau mine, the largest of the district, situated some hundred feet above the low hills just noted, an isolated mass of distorted and broken limestone was found a short distance below the surface, covered by the ordinary products of rock decay. Directly up the slope above the mine is the range summit, capped by horizontal limestone beds. The age of this limestone is yet uncertain, as lack of time prevented search for fossils. The color of the stone is a light gray when fresh, weathering to a darker gray, and, although considerable amounts of iron are present, the rock does not assume the striking colors of the Red Wall beds across the valley. From field considerations, the writer is inclined to believe the age to be that of the Red Wall series, but only careful study can determine this point.



SECTION ACROSS VERDE VALLEY.

FIG. 31.

ROCKS.

No detailed petrographic work was done on any of the rocks of the district, but as the work of Jaggar and Palache covers

all of the rocks but one, and as their field peculiarities may suffice at all times to identify them, the following brief discussion is given.[1]

Schist.—The oldest rock in the region is a metamorphosed sediment, a crystalline schist, or a phyllite with a well developed slaty cleavage. The occurrences are confined to the western portion of the Black Hills, in the lower part just above Agua Fria valley. This valley is itself cut largely from these schists, as shown further south in the Bradshaw Mountain Folio. The strike of the rocks is a little east of north, although in some of the detached fragmental areas the strike changes to west of north. The dip is about vertical, or highly inclined to the east. In appearance the rock is most often of a light gray color, with a lustre like satin due to flakes of muscovite, and with a well developed cleavage wherever seen. The name given to this rock by Jaggar and Palache is Yavapai schist. The age is lower Algonkian, corresponding to the Vichnu terrane of the Grand Cañon geologic column. The Pinal schists of Ransome,[2] in the Globe district, are probably of the same great series of pre-Cambrian sediments. In the Bradshaw Mountains these schists contain many valuable ore deposits; no veins are known in the small area of them west of Cherry Creek.

Granite.—The granitic rocks of the Black Hills in the vicinity of Cherry Creek are of two well defined varieties: a hornblende bearing biotite granite, making up most of the country rock, and a granite porphyry, in the form of dikes intruded into the granite.

The granite is a medium gray rock, with a decided pinkish tint. The grain is somewhat finer than in the same rock further east in the Bradshaw Mountains, the average size of grain being about three mm. The quartz is glassy and colorless, but contains inclusions of magnetite, biotite and hornblende. The largest grains are four mm. in diameter, and the mineral makes up about 35 per cent. of the whole. The feldspar appears to be chiefly orthoclase, cloudy and pink, with a granular texture due

[1] Bradshaw Mountain Folio, No. 126, U. S. G. S.

[2] F. L. Ransome, Professional Paper No. 12, U. S. G. S.

to the stresses and movements in the rock mass. One stout Carlsbad twin observed was four mm. long, but in the main the grains are much finer. Inclusions of the dark minerals are common. The feldspars compose about 40 per cent. of the rock. The biotite, of which there is a little more than 15 per cent. in the total occurs usually in ragged flakes, with a few well formed hexagonal crystals. The largest flakes are six to seven mm. in diameter, of a deep brown color when unaltered. Chlorite has been formed in sufficient amount to impart to most of the mica a green tinge. The hornblende is formed in distinct prisms, commonly small, about two mm. long, but at times in larger crystals up to six mm. in length. It makes up less than 10 per cent. of the rock. The larger prisms are frequently cracked and broken. Spots of secondary hematite are common throughout the whole.

This granite occurs as a direct continuation of the granitic area of the Bradshaw quadrangle,[1] and hence is a portion of the Bradshaw granite, as named by the authors of that folio. An interesting and necessary correlation is yet to be made between the granites of this area and the other known areas north and south.

The granite-porphyry is invariably fractured, shattered and decomposed. Quartz phenocrysts averaging two mm. in size and composing about 40 per cent. of the whole, are set in a fine-grained matrix, granular from earth movements. Ferromagnesian minerals are to be seen only as dark spots. Some limonite in pseudomorphs after pyrite occur. The color is a light pink, due to weathering. The greatest number of the granite-porphyry dikes run in a general north-south direction, varying from N. 38° W., about parallel to the trend of the range, to N. 35° E. The same dike may change its direction within a few feet, as at the Pfau mine. In the main, these dikes dip to the west at moderate angles; in the extreme east the dip is to the east at high angles. A few dikes run east and west, dipping to the north at low angles. The largest dike is the most easterly, that at the Pfau and Pfau Extension mines. This dips steeply eastward, is several hundred feet wide, and strikes at the Pfau mine N. 26° W., at the Pfau

[1] Bradshaw Mountain Folio, No. 126, U. S. G. S.

Extension N. 16° E., and further south N. 34° E. This dike appears to lie approximately in the plane of the steep eastern face of the Black Hills range. The granite-porphyry is in larger masses in the western portion of the range, where its darker color due to weathering serves to distinguish it. The topographic forms produced by both types of granite rock are gently flowing curves with but very rare outcrops. The erosion of the region has removed most of the sedimentary rocks overlying the basement of schist and granite, but this process has not proceeded as far as in the Bradshaw Mountains, where none of the Paleozoic beds are found.

Limestone.—The limestone lying upon the eroded surface of the pre-Cambrian terranes is a fine grained, light gray rock, weathering to a darker gray with a trace of red. It contains considerable amounts of iron, for nodules of rather pure limonite weather out, at times in profusion. As stated above, lack of time prevented a search for fossils, so that the age is not certain. Probably the rock is of the Red Wall series, hence belongs in the lower part of the Carboniferous. If this be so, and proof be forthcoming at a later date, a very important bit of geologic history will be obtained. The unconformity between the granitic basement and the limestone would represent a land mass and a period of erosion covering the time between lower Algonkian and Carboniferous. The alternative of a fluctuating land mass upon which some sediments were deposited and then completely removed before Carboniferous time is less likely, for only a short distance north the geologic column is complete, with the Tonto sandstone at the base. Moreover, the pre-Cambrian land surface reached a well developed peneplain condition in this area.

Basalt.—The basalt areas in the Black Hills cap only the summits of the highest hills, frequently over the limestone. This rock was outpoured in a series of Tertiary flows which now lie practically horizontal. The rock is a typical black lava, called locally " malapai," corrupted from " malpais," meaning bad land. It has been fully described in the writings of the pioneer geologists, and in the later works of Ransome, Jaggar and Palache. No dikes or intrusions of this rock were noted in the district. Its greatest importance lies in its effect upon the topography.

FAULTING AND STRUCTURE.

The faults of the range in the vicinity of the Cherry Creek district are divisible into two main systems: one a north-south, and the other an east-west system. On a second mode of classification, the faults are either pre-Carboniferous, if the limestone of the range top be of Carboniferous age, or post-Carboniferous, including movements up to the present. The older fractures have resulted in the formation of ore bodies; the later have produced the larger features of the present range. The later movements have in general paralleled the first, but are not necessarily coincident with them, There have been no post-Carboniferous movements along the planes of the veins examined.

In a granitic complex, faulting is often largely or wholly obscured, and physiographic criteria, checked by possible stratigraphic evidence, become the sole means of establishing planes of motion. In the Black Hills such evidence is not lacking, although the facts obtained are fewer than could be desired.

In outline, the section across the range at Cherry Creek, from east to west, shows first a steep rise from the valley of the Rio Verde to the summit, then a few miles of crest westward, passing into a comparatively gentle slope down to the Agua Fria valley. In other words, the curve through the hill tops would be an asymmetric arch, whose greatest elevation would be just above the steep eastern slope. It would seem, therefore, at first sight, that the granite exists merely as a huge dome, elongated north and south, whose larger form is due to its intrusive genesis. And such Marvine[1] assumed it to be. The limestone and basalt remnants do not, however, support this view. The steep eastern slope of the range is almost beyond doubt a fault cliff. At the summit, but westward a few hundred yards, the limestone lies horizontal upon the granite; at the base, a nearly horizontal series of sedimentary beds occur, abutting against the granite. At the Pfau mine, as already noted, a detached and broken mass of limestone was found below the surface on the granite slope. A full discussion here would be premature, as the whole range has not been

[1] Wheeler Survey, Part III., p. 208.

studied in detail, yet it is safe to assume that either a fault or a very sharply flexed monoclinal fold exists. The presence of other unmistakable north-south faults causes the balance of proof to fall on the side of a fault scarp forming the eastern face. Also, the profile of the bed of Cherry Creek adds to the probability of a large fault scarp. In the upper reaches this stream flows in a wide, flat bottomed bed, with a gentle slope. Some portions are of greater fall, indicating earth movements, but in general the stream has reached a mature stage. On coming to the eastern slope, however, the grade is abruptly changed, and topographic youth is strikingly apparent. The accompanying section expresses the main facts of the structure.

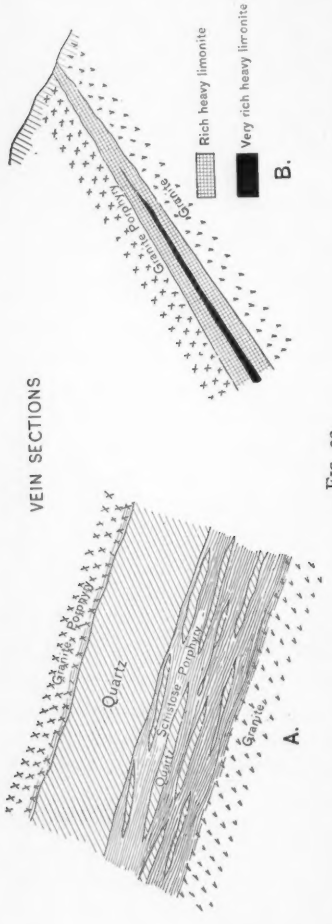


FIG. 32.

Earlier Faults.—The criteria for the proof of faulting before the granitic complex was baseleveled and covered by later sediments, lie entirely within the vein structure. The veins end beneath the limestone, with no continuation of motion upward into the overlying rocks. The veins are all associated with granite-porphyry dykes, which were themselves probably intruded along lines of movement when the mass was

in a semi-fluid condition. Later motion opened crevices within these dikes, the movement at this time being shown by the production of schistose granite and by the shattering of the dyke rock. Still later the veins were further opened by earth movements and more vein material deposited. These later movements were of varying and irregular intensity, as the second deposition of vein matter was unequal in the different veins. Finally, the dikes with their included deposits were greatly fractured, and the veins became open to surface agencies.

Later Faults.—The presence of faulting later than the deposition of the younger rocks is shown best by stratigraphic evidence. On Cherry Creek below the post office, where the stream flows in an east-southeast course, the south bank rises to a mesa capped by several hundred feet of basalt, while the north bank rises to the flat topped granite hill shown in figure 33 just above the eastern slope of the range. The unconformity is fully apparent. This line of movement is parallel to the outcrop of one of the larger east-west veins, which outcrops on the north bank just above the creek bottom. Also, in figure 33, the presence of a north-south fault is shown between the two hills, one capped with limestone, and the other of granite only. Many other instances can be cited, but these two are typical. The examination of the topography shows that a careful application of physiographic tests, when no rock but a crystalline one be present, may prove the existence of faulting. The stream valleys are prevailingly wide and flaring, the fault valleys are typically narrow and sharp cut. Also, the stream reaches in the granite indicate where differential motion has occurred. On this line of investigation, much unmistakable evidence for widespread faulting across the whole range can be obtained. The structure, then, can be summed up thus. The Black Hills range is due to differential uplift of a granite mass, the maximum elevation taking place on the east side. The essential lines of motion run northerly and southerly, parallel to the range; secondary movements occurred east and west, dividing the range into blocks, the detailed investigation of which is yet to be made.

ORE DEPOSITS.

Condition of District.—The Cherry Creek mining district produces some gold at present. Considerable prospecting is being done, and in time the region will figure as worthy of general attention from mining men. One mine is milling from one hundred to two hundred tons a day, and a second is shipping to Prescott a fair amount of smelting ore.

No deep prospecting has yet been done, the greatest depth yet reached by shaft, August, 1905, was only a little over one hundred feet, and an adit tunnel on another property was in about two hundred feet below the vein outcrop.

Veins.—As with the faults, two systems of veins exist. The major portion of those observed have a northerly strike and westerly dip; a few have a northerly strike and easterly dip, in the eastern part; a few have a westerly strike and a northerly dip. Both classes of veins have identically the same character of filling. The width averages about three feet at the surface, increasing with depth.

The veins occupy broken and sheeted zones within the porphyry dykes, which have been, subsequent to their formation, opened by later movements and new vein filling introduced. The earlier portions of the veins consist of stringers of quartz and ore in schistose and bleached granite-porphyry, the extraneous material making up usually less than one half the total width. Some of the veins have not advanced beyond this stage; the best of them have. The later fissuring, attended by faulting, has resulted in comparatively strong veins of massive quartz, above or below the first deposit, often forming the hanging wall of the dike. The latest movements in the veins have fractured the hard vein filling and opened the minerals to surface agencies, resulting in great secondary concentration of ores. Even the secondary surface ores have been reconcentrated in some instances. The accompanying sketches shown in Fig. 32 will give an idea of some of the typical veins.

Ores.—At present the mines are developing an oxidized, free-milling gold ore, with traces of sulphides with depth. The typical ore is heavily charged with limonite, locally called hematite, with

an aphanitic texture, and contains gold in bright shining flakes. The richest ore is nearly pure limonite, usually with some small amounts of silica. No other gangue minerals are found. With depth, kernels of unaltered pyrite are frequently found in the heavily oxidized ore, and this sulphide, together with chalcopyrite and bornite, occurs at times in isolated masses up to eight inches in diameter. In a few cases residual pyrite was found in the outcrop. The western viens have not yet shown copper minerals, chiefly because of lack of depth. This sulphide ore is invariably rich.

In the upper portions of the veins, the bleached and broken country rock is often milled as ore, though of low grade. On one mining claim a vein dips with the surface of the mesa, forming a dip slope. This has the peculiar result of causing the whole hillside to pan free gold and yield assay returns at times quite large. Such ore as this is almost entirely decomposed granite porphyry and granite, with a small amount of fine quartz fragments.

These peculiar aphanitic limonite ores, frequently contain-

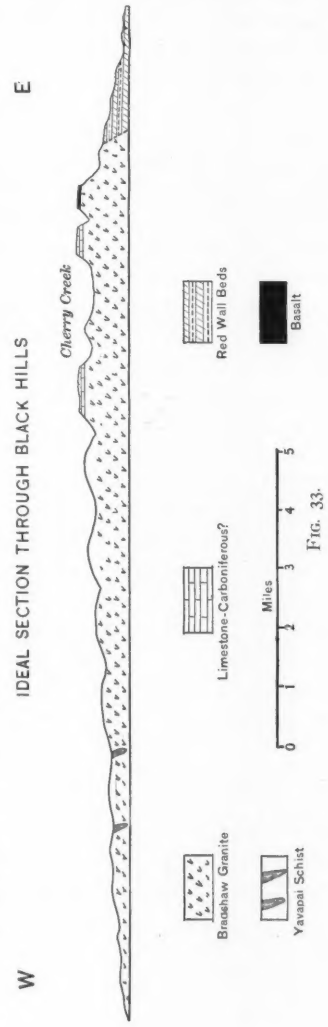


FIG. 33.

ing bright flakes of hematite, are not uncommon over the arid regions from Nevada southeastward. The chief interest connected with them lies in the controlling processes of secondary change. This is particularly true at Cherry Creek where the limonite-gold deposits change to copper deposits with depth.

SECONDARY CHANGES.

It is in the phenomenon of secondary deposition of minerals that the ores in the Cherry Creek district are peculiar and interesting, both from a mining and from a scientific standpoint. The development work in the mines has not yet progressed far enough to exhibit all the changes which have occurred, yet there can be no doubt that the four zones of Emmons[1] are almost ideally developed. Furthermore, the veins already opened show the instability of any one set of geological conditions, for the zone of impoverishment is invading the zone of rich oxides, which in turn is encroaching upon the rich sulphides below. The causes operating to make possible these continued changes are easily found. At least three distinct sets of movements fracturing the vein filling and enclosing dikes have occurred, so that the vadose waters have been free to circulate. The present water level in the mines is strikingly different from what it must have been in times past, for permanent water is found at about sixty feet, or even less in some mines, below the surface, while the heavy oxidized ore continues downward to unknown depths. A recent wet year is largely responsible for present conditions, but not entirely, for before the rains of 1904–5 the mines were water-bearing in some degree.

The zone of impoverishment, because of the continued leaching it is undergoing, presents several interesting features. As discussed by Emmons,[2] Weed[3] and others, this surface zone is characterized by low values, or lack of values, containing usually nothing but oxides of iron and silica. In Cherry Creek, however,

[1] S. F. Emmons, "Secondary Enrichment of Ore Deposits," *Trans. A. I. M. E.*, Feb., 1900.

[2] S. F. Emmons, *Trans. A. I. M. E.*, Feb., 1900, pp. 463-464.

[3] W. H. Weed, "Enrichment of Silver Veins," *Trans. A. I. M. E.*, Feb., 1900, p. 476.

a subzone of further impoverishment exists, from which not only the values have been leached, but also the iron oxides and even silica have been partially or very largely removed. The two factors of age and openness of veins have been chiefly responsible for this. At the surface, quartz, in most veins, outcrops in stringers and larger masses. Such surface quartz is not often prominent, because of the shattering of the material, although hard boulder-like fragments occur, surrounded by softer rock. In a few veins the outcrop is prominent, and is composed of quartz stringers in granite porphyry, the hard mineral restraining the erosion of the whole. Limonite, in stringers and veinlets, cements

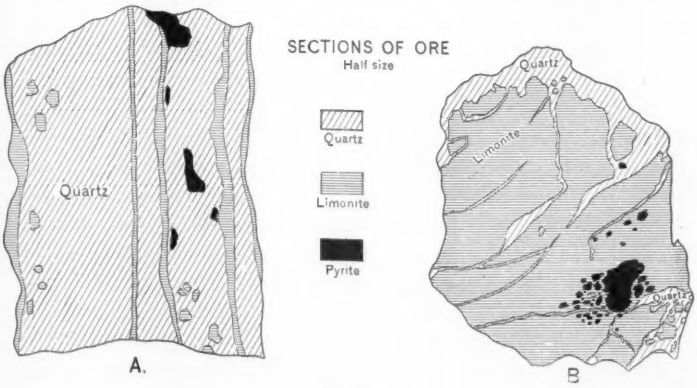


FIG. 34.

this broken quartz. The iron oxide frequently appears as pseudomorphs after pyrite, the form of the pyritohedron being very common. The main direction of breaking is parallel to the plane of the veins, hence the larger veinlets of limonite are more or less parallel, giving a rough effect of ribbon structure (see Fig. 34, *A*). Below the outcrop a few feet the quartz and contained limonite decrease in abundance, frequently disappearing entirely. Assay values showed the same, returns from the surface being notably higher in the majority of cases than five or ten feet lower down. Furthermore, in the instances where the quartz has only partly gone, the iron oxide has almost entirely been carried below, taking

with it the gold values. In one of the larger east-west veins, the upper seventy-five feet has been thus leached of all but a trace, while below this depth good ore exists in quantity.

After the barren, or nearly barren, portion of the veins has been passed through, heavy rich limonite in quartz is encountered. The aphanitic texture is always prominent, and small shiny areas of unaltered pyrite are frequently present in the midst of the heaviest iron oxide (see Fig. 34, *B*). Secondary quartz, at times jaspery, is noticeable in this portion of the veins, and occurs both in irregular patches and in small veinlets in the limonite. The heavier the oxide, the larger the amount of secondary silica. At the Golden Idol mine, in which the vein material is about 90 per cent. iron oxide, the limonite extends to the surface. The outcrop is eighteen inches wide, assaying a low value; forty feet down the vein is five feet wide, of almost solid rich limonite, with a very rich ten inch streak in the center. The center streak is well defined and clearly a deposit later than the inclosing material (see Fig. 32). In the bottom of the workings rich sulphide ore is commencing to show, below the present water level. In the phenomenon of the veins being narrowest at, or just below, the outcrop, it is to be noted that the walls in the narrowest portions show evidence of lateral pressure and crushing, attendant upon the removal of material from between them.

At present writing the zone of secondary sulphides has been merely touched, only residual fragments of these minerals having been extracted. Their occurrence, however, demonstrates two facts: first, the actual presence of a zone of secondary sulphide enrichment; and, second, the gradual migration of this zone downward. The sulphides found are extremely heavy, and constitute some of the very richest ore. In the western veins copper sulphides have been found only in small amount; on the eastern slope chalcopyrite and bornite are found in increasing amount with depth. Not the most minute traces of oxidized copper minerals have been seen in any port of the district. At the Pfau mine, situated in the large dike on the east slope of the Black Hills, the ore is apparently very thoroughly oxidized, yet a search in material from the lower levels will be rewarded by lumps of copper

iron sulphides, often eight inches in diameter, covered with a half inch shell of earthy limonite. Chalcopyrite is in larger amount than the bornite. Pyrite occurs in the higher portions, just as in the western veins.

The peculiarity, then, of the secondary deposition of minerals is evident. The zone of oxide enrichment contains limonite and quartz, with free gold, and no traces of copper. The small amounts of sulphides are pyrite toward the surface, changing into copper minerals below, these latter minerals being best developed in the eastern veins. Further, the double sulphides of iron and copper are found exclusively, no chalcocite or covellite being present. What may be below is of course problematical, but it would not be surprising if the simple sulphides were there in abundance. It is worthy of note, in this connection, that the United Verde mine at Jerome was worked solely as a gold mine in the early stages of its history, and had a precarious existence until the rich copper ores were struck in depth.

In the typical copper vein the oxidized zones contain copper minerals, often in great abundance, and outcropping on the surface, as at Globe, Bisbee and Clifton, in southern Arizona. At Cherry Creek and Jerome, such oxidized copper ores are conspicuously absent, while the surface zone is wholly or partly leached, not only of its values, but also of its gangue. The conditions causing such a result are of two kinds: structural and chemical. The structural conditions are those of movements in the veins, shattering the country rock as well as the vein stone, thereby opening well the ores to surface agencies. The chemical conditions are, in their nature, more obscure, and can only be surmised at this writing. Azurite, malachite, cuprite, and chrysocolla, are stable under the common conditions found in the oxidized zones in copper veins, so that their complete absence proves the existence of a situation chemically somewhat unusual. Also, the peculiar effects noted in the veins at and just below the surface call for explanation. The most notable characteristics of the veins are: (1) The abundance of limonite; and (2), the prevalence of a gneissic or schistose structure accompanying the veins, and the bleaching of the rocks by the action of sulphuric

acid. At times the action of the acid has proceeded sufficiently far to produce from the rock a white pulverulent mass. This intense action is always found in the very summits of the veins just below the outcrop.

The first striking feature, the quartz outcrop followed below by a vein filling, poor in all constituents of foreign source, can be easily explained. The active solutions start from the surface, enter the vein, and because their power is least at the start, and because fresh oxygen-bearing water follows, the actual outcrop is comparatively little attacked. On the other hand, the solutions passing through the first foot or two of surface vein filling, and taking up the acid found therein, are held in contact for some time with that portion and their leaching action becomes intense. The deposition of the material thus taken into solution necessarily follows as the waters percolate downward.

Secondly, with an abundance of iron and sulphuric acid, and with the free access of oxygen, the secondary copper minerals, so commonly found in the upper portions of veins, could not form The cupric sulphate, produced both by the free acid and the ferric sulphate, would be carried down to the bottom of the zone of oxidation. Under these conditions the gold would also be leached from the surface and deposited on the oxidation of the iron salts to hydrate. Silica would also be deposited as the character of the solutions change. Rickard,[1] in his valuable paper, has presented the main facts regarding the enrichment of gold veins, although he leaves rather in abeyance the fact that sometimes gold migrates and at other times it does not. The migration in the Cherry Creek district is no doubt chiefly caused by the very large amounts of ferric sulphate present, aided possibly by chlorides from the overlying limestone. It is not clear exactly what solvents are responsible for the downward movement of the silica. That silica does so move is well known; witness the frequent sintery quartz of vein outcrops. Also, at the Comstock Lode, the vadose waters, containing 11 per cent. of soluble sulphates and 12½ per cent. of free sulphuric acid, hold in solution .55 per cent.

[1] T. A. Rickard, "The Formation of Bonanzas in the Upper Portions of Gold Veins," *Trans. A. I. M. E.*, Feb., 1901.

of silica. Simple equations expressing graphically the relations outlined above, could be written, but it seems inadvisable to do so until our precise knowledge is greater.

A further point is this: Among secondary sulphides present, those bearing copper are invariably the double salts of copper and iron, with chalcopyrite in larger amount. The reasons for this may also lie in the excess of iron and sulphuric acid present in the vein. The presence of sulphuric acid necessitates a plentiful supply of oxygen, which is not at all at variance with the facts of vein shattering. If equations be written expressing the probable reactions producing the minerals chalcopyrite, bornite and chalcocite, or better, general equations summing up all intermediate reactions, it will be found that, in the main, chalcocite will form when the ratio of the copper to the iron is as 2 : 1; bornite when this ratio is 3 : 2, or, when both iron and a strong reducing agent are in excess, 3 : 1; chalcopyrite when this ratio is 2 : 3, or, when a strong reducing agent is present, 1 : 1. As the veins have been well opened to oxidizing solutions, in the upper portions of the veins strong reducing agents were lacking. In this case, these ratios of copper to iron for chalcocite, bornite and chalcopyrite are 2 : 1, 3 : 2 and 2 : 3, respectively. Thus, the excess of ferric salts and lack of strong reducing agents would favor the formation of double sulphides. It is needless to state that the whole subject of the physical chemistry of this comparatively simple process of secondary enrichment of copper ores, is in need of thorough experimental treatment before we shall be in a position rightly to interpret the facts. The working geologist lacks time and often the requisite knowledge for pursuing such investigation, and must, perforce, depend upon the labors of others. At Cherry Creek, however, the facts in the field, such as the great abundance of limonite with frequent kernels of pyrite, the vein shattering, and the bleaching action of sulphuric acid, appear to warrant the tentative conclusions above set forth.

PROBABILITIES WITH DEPTH.

With depth it is almost beyond doubt that the gold values will decrease, while the copper will increase in amount. At what

depth a pronounced change will be found it is not possible to say. The deepest mine workings show ore thoroughly oxidized, with the exception of a few residual sulphide masses, and practically of the same chemical nature throughout. The ground water now being well above the bottom of the zone of oxide enrichment offers no criterion, but proves only the existence of a more arid past. The gold values will continue through the zone of oxidation and into the underlying zone of secondary sulphides, and there should be considerable depth to the gold bearing minerals. If the above ideas regarding the genesis of the double sulphides be correct, it is possible that chalcocite may be found with greater depth, formed after much of the iron has been left behind as limonite. In any case, there should be an abundant supply of good ore, both with gold values and with copper as the chief metal.

THE FORMATION OF ASPHALT VEINS.

GEORGE HOMANS ELDRIDGE.

INTRODUCTION.

Asphalt veins as they occur in the superficial strata of the earth's crust afford a study in black and white of many features of ore deposition in general. Such veins are not only easy to follow when they are once opened, but they are often clearly marked across the country, especially where the surface is formed by a resistant rock rather than by one readily disintegrating into soil. It is possible indeed in certain instances to follow the outcrop of a vein for several miles by simply occupying some prominent point along its course and turning the eye in either direction.

Not only is the study one of simplicity, due to a sharp contrast of the black asphalt with the lighter colors of the adjacent rocks, but even in the character of soils and verdure the course of the vein is marked, either by a complete absence of plant growth or a change in the character of the vegetation. While these elements of contrast are to be observed in most occurrences of asphalt veins they may be studied under exceptionally favorable conditions in the enormous gilsonite veins of Utah.

OCCURRENCE OF ASPHALT VEINS.

Distribution.—As actually observed by the writer, asphalt veins occur in many parts of the United States, both east and west, in Cuba and in many other parts of the West Indies. By reference to literature on the subject it is evident that they are scattered through most of the explored territory of the earth and that they are of far wider distribution than veins of metalliferous materials. This is doubtless due to the limitation of metalliferous veins to the proximity of deep-seated mineral-bearing waters which have found a passage either through the older, crystalline rocks, or through such of the later sedimentaries as have been violently folded or otherwise rendered pervious. The wider

occurrence of asphalt veins is due also to the fact that petroleum, the mineral from which the asphalt has been derived, has an extensive distribution in the stratified rocks from the oldest to the youngest. In the crumpling to which the crust of the earth has been subjected such strata have frequently been folded and then exposed by erosion.

It will be found in the study of what follows that there is no marked difference in vein phenomena, whether the fissures be filled with bituminous matter or metalliferous ores and gangue, either from point to point on the veins, or from formation to formation which they traverse. The character of an asphalt vein depends largely on the nature of the country rock and this is also the case in deposits of metallic ores.

Nature and Origin of the Fissures.—The purer varieties of asphalt occur in fissures, and it is to these that the present discussion is confined. The formation of all fissures in the rocks of the earth's crust has been brought about by one or the other of two causes—folding or contraction. When fractures are due to folding a displacement of the originally adjacent walls has often taken place while in the fissures produced by contraction this does not necessarily occur.

To assign the origin of a fissure to the latter cause is, however, often attended with considerable uncertainty, because lack of displacement may accompany phenomena of the first class. The greatest asphalt-filled fissure in the world is one in which there is no displacement, the vein having a maximum width of eighteen feet and a length of no less than ten measured miles. Others occurring nearby are only a little smaller and in addition display the phenomenon of forking. In both instances the veins trend in the direction of the dip of the enclosing strata. They are, therefore, more probably the result of contraction than of folding, the axes of the flexures trending at right angles to the veins.

To what such contractions of the strata are due it is impossible to say, and it is also impossible to ascertain the causes which have determined the directions assumed by the fissures. Contraction is supposedly the result of loss of heat or of moisture, the latter having taken place during the drying out of the beds. The for-

mation of such fractures must have occurred while the strata were deeply buried beneath overlying measures, and it may be that as originally formed they were characterized by little or no displacement. If so they are comparable to minute rifts that occur in new excavations of the present day. In a measure this might account for the many instances in asphalt veins in which there has been no displacement of the adjacent walls. This is perhaps not such a remarkable occurrence when the depth at which the fractures occurred is considered and when the extent of the cracks is brought into direct comparison with the vastness of the measures which they have affected.

Dimensions of Veins and their Relation to the Enclosing Rocks. The lineal extent of asphalt-filled fissures varies from a few feet to many miles. In width the fissures, when single and uninterrupted by horses or inclusions that have fallen in from the walls, range from a maximum of eighteen feet down to extremely fine, thread-like crevices whose length is always disproportionately great. A clean fissure frequently attains a width of several feet.

In most cases instead of a simple fissure a zone of fissures has been formed in which a large number of separate fractures occur, the smaller ones interlacing with one another and the whole network together affording a large aggregate space for the passage of the material with which the fissure is filled.

This latter mode of occurrence is the more interesting as it affords a close parallel to characters more commonly found among veins which carry metallic minerals, particularly those in areas of crystalline schists or in the sedimentary slates of more recent geologic epochs. Simple ore-filled fissures on the other hand are usually confined to heavy-bedded rocks such as limestone and sandstone or to massive granitic rocks.

Among asphalt veins are found some remarkable examples of tenuity. In the region where the wonderful veins of Utah are found the writer has observed one instance of an uninterrupted asphalt-filled fissure of a width not exceeding one half an inch and a lineal extent of fully four hundred feet. It appears at the surface as a jet black line and when viewed from a distance resem-

bles a carbon crayon mark drawn on the eroded surface of light colored yellowish gray sandstone.

The downward extent of the fissures is more difficult to determine and must, in the absence of deep workings, remain uncertain. In general, however, the vertical range of the more persistent veins of clear material is greatest in massive beds of sandstone, indeed it is practically coextensive with the thickness of the enclosing rocks. It is thought that the great Cow Boy vein in eastern Utah had, before erosion affected the strata, a vertical range of at least 2,000 feet, which is the thickness of the massive sandstone in which it occurs.

In addition to the long straight veins another type may often be noted in which the veins show a closer relation to the folded structure of the enclosing rocks and exhibit a higher degree of complexity.

An excellent illustration of this type may be seen in one of the asphalt districts of Cuba. The veins are located on the nose or easterly end of an anticline. On the sides or limbs of the fold at some little distance from its downward pitching extremity are one or two normal strike fissures. As one approaches the end of the fold the rocks become relatively broken and crushed and the regularity of the strike fissures is lost in the complexity of the interlocking fractures. The general trend of the zone of fracturing, however, continues as a whole to follow the strike of the beds, curving around the pitching end of the fold and connecting the strike fissures on the one limb with those on the other.

The strata in this case comprise a succession of thin-bedded limestones and calcareous clays. The limestones predominate but the clays are in sufficient abundance to give to the measures a thinly laminated character, rendering them, in a sense, transitional between a typical heavy-bedded and a typical shaly series. The veins, therefore, are likewise transitional, neither as regular as those usually found in heavy-bedded rocks nor as irregular as those in shales.

Relation of the Veins to the Enclosing Strata.—The character and value of the veins are dependent on the type of rocks in which they occur. Those which are found in the more heavy-

bedded rocks are the more regular, those in thinly laminated shales are often extremely irregular. When a vein passes from a heavy-bedded rock above or below into shales, it generally splits into a number of fissures of smaller dimensions. These then follow divergent directions ramifying through the shales in an intricate manner, and are, with few exceptions, without value. Occasionally great bodies of asphalt are to be found in clay or shale beds, but they are in the nature of pockets. These pockets may occur singly, or several may lie along a single crack or zone of fissuring, connected through the intervening spaces by minutely ramifying fissures almost void of bitumen. Many of them have been mined in the western part of the United States, but have in all cases, sooner or later, proved unprofitable, and have been abandoned. The regular fissures in the massive sandstones have so far been the only deposits of commercial value.

COMPARISON WITH METALLIFEROUS VEINS.

Horses.—Veins of asphalt show the same peculiarities of structure as those of the precious metals, but on account of the contrasted colors of the vein matter and wall rock these may be much more readily observed. This is particularly true in the case of included fragments of country rock, for in a vein of asphalt there is never any difficulty in recognizing horses of rock that have fallen in from the walls. Indeed it is often possible to determine the precise position which they originally held upon the wall, as the distance through which they have traveled is often less than three feet. At other times a body of rock hangs by the merest thread to the wall on the one side or the other of the fissure. The size of the horses that have been observed by the writer varies from a few inches to five or six feet in width and in length from three or four to twenty or thirty feet.

Movement along Fissures.—The walls of the fissures frequently show slickensides indicating a movement in the direction of the markings. This usually coincides with the direction of the vein but the amount of movement seems generally to have been small as it is often difficult to detect any relative displacement of the rocks on the opposite sides of the fissure. Another evidence of movement is the variation in width which the veins sometimes

exhibit. In most cases, it is true, they are comparatively regular but pinches and swells forming bonanza-like pockets occasionally occur. These are connected with one another by constricted portions of the vein which contain little bituminous material. Such variations are usually explained in metalliferous veins by displacement. The fissure having had an undulating course in its downward extension the subsequent movement has brought the concave and convex portions opposite to one another, forming a constriction between two convex and a widening between two concave portions.

The presence of shoots following diagonal downward courses in the vein, a feature so often observed in metalliferous veins, has not yet been detected as exploitation has not been sufficiently extensive to reveal them.

THE GENESIS OF ASPHALT VEINS.

The genesis of asphalt veins involves much uncertainty. The question is readily divided into two distinct phases: (1) origin of the material which fills the fissures; (2) the immediate source from which the asphalt has been derived and the manner in which it was introduced into the fissure.

Origin of Material.—There is little question at the present time that the asphalt has been in some manner derived from petroleum, although the exact process by which this has taken place is not yet clearly understood. Among the evidences which prove that petroleum is the source of the asphalt none is clearer than that afforded by the remarkable parallelism of asphaltic and petroleum products. Thus there are amongst the oils a dozen different types: napthas, illuminating oils, lubricating oils, and natural residual oils, each of these exhibiting several varieties of composition. In the same way among the asphalts there are grahamite, albertite, gilsonite, wurtzelite, ozocerite, negrite, and the simple variety of the hardened oil which passes under the name of asphalt. The chemical and physical properties of these series show a close correspondence which may even be extended to the minor subdivisions of the several groups. It is, therefore, not so remarkable that with the different types of oils as an original source there should be a corresponding series of asphaltic products

derived from them. In some cases the evidences of such derivation are of a geological character and are susceptible of actual observation. A bed of paraffine has recently been found in Alaska on the western shore of Cook Inlet presumably associated with a fissure and from the manner of its association has unquestionably resulted from an outpouring of a light illuminating oil of paraffine base.

While the similarity between oils and asphalts thus affords us practically conclusive evidence as to the derivation of the latter from the former, it does not afford a clue as to the ultimate origin of the petroleum itself.

Manner of the Filling of the Vein.—It seems highly improbable that the petroleum or asphalt was formed as such in the fissure. Indeed the manner of its occurrence serves to disprove such a supposition. It is much more probable that it was introduced into the fissure from original deposits in the neighboring strata or from rock reservoirs in which it had been previously accumulated. A study of the rocks associated with these veins will serve to throw some light upon this question. These are in all cases sediments; either sandstones, shales, clays or limestones, or alternating beds of one or all of them. While the sandstone rarely shows impregnations of asphalt the limestones, shales and particularly the clays do show such impregnations. The limestones and shales are also more or less richly impregnated with bitumen. The first impression which one receives when considering these facts is that the asphaltic material which fills the veins has been derived from this disseminated bitumen. It has not thus far been observed, however, that the shales or limestones adjacent to the veins have been deprived of any portion of their bituminous contents. The explanation of this phenomenon may be that in the passage of the petroleum from the shales into the fissure, the material first having its exit into the cavity has been followed by other material behind and so on, until the operation has been brought to a close by the complete filling of the opening. The fissure and the adjacent strata are thus left filled with bitumen, and only that territory which is somewhat remote has been drained. Under the most favorable circum-

stances it would be a difficult matter to determine whether such remote territory had suffered a loss of its original content or had not at any time contained appreciable amounts of bitumen. The occurrence of oil well phenomena of the present day affords some confirmation of this theory of the flow of petroleum to a fissure, as the adjacent strata are exhausted. The oil wells which are large producers may be considered as taking the place of the natural fissures, inasmuch as such fissures would tend to exhaust the supply in much the same way as the series of productive wells. The oil in a productive region flows from the adjacent strata into the wells and from the more remote strata into the adjacent strata, until the entire pool has been depleted. If the flow be checked prior to complete exhaustion, the well and the adjacent strata are left full rather than the strata which are more remote. We should, therefore, expect the same sequence of events to take place during the formation of asphaltic veins.

Without entering into the difficult question of the flow of liquids at great depths below the surface, it seems well to venture upon a suggestion as to the manner in which the oil has been moved from its original position into the vein. The asphalt veins may have been formed either with or without an opening to the surface. In most cases it is presumed that no connection with the surface existed. In such a case a vacuum would probably have been formed here when the fissure was opened and a powerful suction exerted upon the disseminated bitumen in the surrounding rock. It is probable also that the flow of material to the fissure has been aided by an expansion of the gases associated with the oil, such expansion occurring at the moment when the formation of the fissure relieved the pressure. The hydrostatic pressure of a salt water column as shown by Orton may further have operated in a similar manner to accelerate the introduction of material into the fissure.

In those cases where the asphalt-filled fissures actually extended to the surface (and the evidence of such an extension may often be seen in the presence of an overflowing brea deposit) the expansive force of compressed gases and the weight of the hydrostatic column must have been sufficient to overcome the resistance of the air in the cavity.

COPPER DEPOSITS OF THE EASTERN TOWNSHIPS OF QUEBEC.

JOHN ALEXANDER DRESSER.

INTRODUCTION.

The name "Eastern Townships" is applied to that portion of the province of Quebec which is comprised in the northward extension of the Green mountains into Canada. The hilly character of this district and its less accessible position delayed its settlement until nearly forty years after the cession of Canada to England. It was then surveyed according to the English mode of division of lands into townships that are approximately square, instead of the narrow oblong parishes of the French method of survey.

The Green mountains in Canada are sometimes known as the Notre Dame Hills. They determine the eastern edge of the flat St. Lawrence valley, and extend northeastward from the boundary line between Vermont and Quebec for a distance of about one hundred and fifty miles, or nearly to the latitude of Quebec city. The highlands of Gaspé, commonly called the Shickshock Mountains, are the extension of the White Mountains of New Hampshire, or of some more easterly range of the Appalachian system. From these the hill country of the Eastern Townships is separated by a considerable interval.

The main geological features of the district are three belts of crystalline rocks which are probably pre-Cambrian in age, separated by Paleozoic sediments, which are almost wholly of pre-Devonian age. These relations may be clearly understood by a glance at the map, Fig. 35. The crystalline rocks are composed of altered sediments, tuffs, and true igneous rocks. The igneous rocks consist of a series of porphyries and andesitic rocks, and of a serpentine-diabase series.

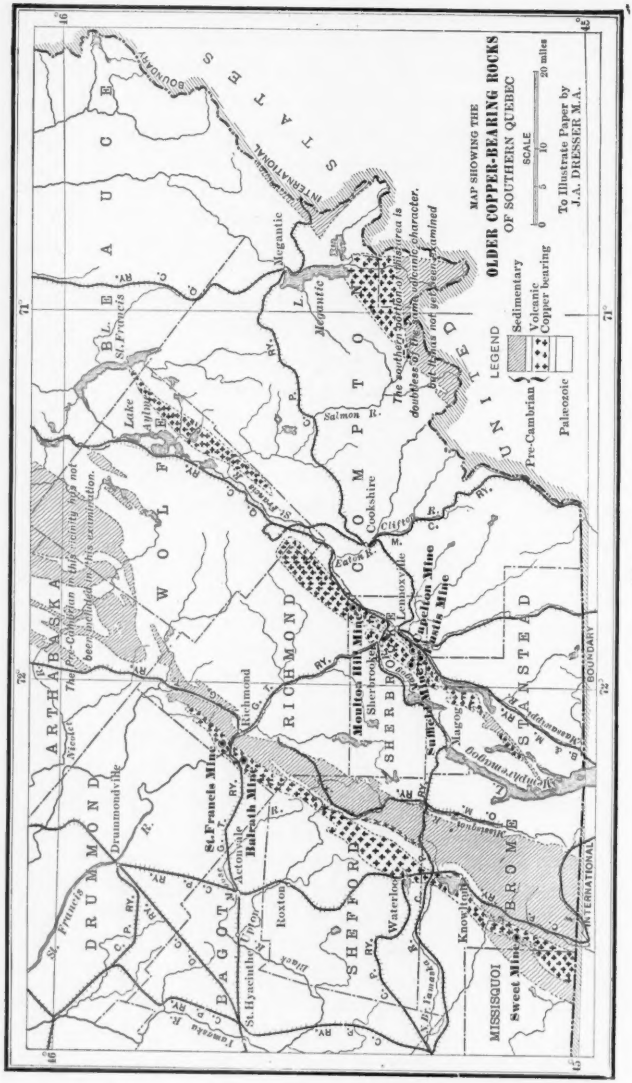

MAP SHOWING THE
OLDER COPPER-BEARING ROCKS
OF SOUTHERN QUEBEC
LEGEND
Sedimentary
Volcanic
Copper bearing
Pre-Cambrian
Paleozoic
SCALE
0 5 10 20 miles
To Illustrate Paper by
J.A. DRESSER M.A.
INTERNATIONAL BOUNDARY
Megantic
Lake Aylmer
Salmon R.
Cookshire
Eaton R.
Clifton
Lennoxville
Capelton Mine
Huntley Mine
Weedon
Nicolet
Richmond
Sherbrooke
Moulton Hill Mine
Ascot
Magog
Orford
Lake Memphremagog
Massawippi
Coaticook R.
Drummondville
St. Francis R.
Actonvale
Balcath Mine
St. Francis Mine
Roxton
Waterloo
Knowlton
St. Hyacinthe
Yamaska R.
Sweet Mine
Missisquoi
Stanstead
Brome
Sherford
Drummond
Dagot
Wolfe
Richmond
Compton
Arthabaska
Beauce
Megantic
The Pre-Cambrian in this vicinity has not been included in this examination.
The southern portion of this area is doubtless of Pre-Cambrian character, but has not yet been examined

FIG. 35.

THE ORE DEPOSITS.

MINING IN THE EASTERN TOWNSHIPS.

The occurrence of copper in the Eastern Townships was known as early as 1841, in which year Sir William Logan examined a copper property at Carbuncle mountain, Brompton Lake. This was one year prior to the organization of the Canadian Geological Survey of which Logan was the first director.

In 1847 the Geological Survey report called attention to the deposits at Upton, and the reports of succeeding years mentioned or described other localities, until a compilation of those in 1866 gives a list of about five hundred localities in which copper was known to occur in the district. This mineral was vigorously sought for and extensively mined between the years 1859 and 1866. With the decline in the price of copper which followed this time, from about thirty-five to nine cents per pound, the mining operations received a very severe check and work for a time almost ceased.

In this earlier work copper was the only product of the ore that was then of any considerable value, and the richest sulphide ores were discarded when the percentage of copper was low. After the intense speculative wave had passed, notwithstanding the low price of copper, between 1875 and 1885 several properties were reopened or changed management and were worked on a better economic basis. Not only were the metallic contents of the ores, except the iron, utilized, but the sulphur was also saved for the manufacture of sulphuric acid and allied products. Thus some of the reopened properties have been worked continuously for about thirty years, *i. e.*, ever since their operations have extended to the utilization of the sulphur. A depth of three thousand feet, or thereabouts, has been reached, and although detailed reports are not available, the continually increasing scale of operations at least indicates no diminishing of the works at these well-managed and successful mines.

CLASSIFICATION OF THE DEPOSITS.

The copper deposits of the Eastern Townships are of three distinct classes:

1. Ores, chiefly chalcopyrite, with small amounts of chalcocite and bornite, and relatively unimportant amounts of other ores, principally carbonates and pyrite. The ores of this class occur in the porphyry-andesite schists, the oldest rocks of the region. They form lenticular bodies, apparently occupying crevices, or more likely, have replaced the rock along lines of weakness produced in the course of the intense folding to which the region has been subjected. The gangue, when distinct from the country rock, is generally quartz, though sometimes calcite.

2. Chalcopyrite, bornite and chalcocite, with small amounts of carbonates compose the deposits of the second class. These occur as irregular bodies in Cambro-Silurian sediments where the latter are invaded by certain intrusives. The gangue is largely calcite.

3. Chalcopyrite in pyrrhotite, with a little pyrite, forms the third class. The deposits of this class are situated along the contact of Cambro-Silurian strata with the intrusive diabase of the serpentine series. They are distinguished from the ore bodies of the second class, not only by the character of the ore and the presence of pyrrhotite, but apparently also by the fact that the second group are generally exomorphic contact bodies, while the third are principally endomorphic features of the contact. Moreover, the intrusives of the former are only dikes of comparatively small volume, but those of the latter class are large mountain-forming masses. The country rock of the second class of deposits is limestone wherever they have shown any important dimensions, with one possible exception, but in the third class it is an iron bearing slate or other metamorphic rock of the district.

A few of the characteristics of the ore bodies of the first class only will be presented in this paper.

CHALCOPYRITE AND PYRITE DEPOSITS.

Distribution.—The deposits of this class include the principal basis of work in the early development of the district, and of all the ore bodies that are at present exploited. They comprise three principal groups:

(*a*) Some fifty mining properties and prospects, of more or less promise, in the township of Ascot, and other townships near

the city of Sherbrooke. Amongst these are the Eustis, Capelton, King, Suffield, Ascot and other less known properties.

(*b*) The series of deposits long known to extend through the townships of Sutton, St. Armand, Bromo, Shefford, Ely, Melbourne, Cleveland, Shipton, Tingwick, Arthabaska, Chester, Ham, Wolfestown, Inverness and Leeds, as well as the divisions of the seigniory of St. Giles, known as the Handkerchief, and Ste. Marguerite, in the county of Lotbinière.

(*c*) Deposits in the little known district along the boundary line between the province of Quebec and the state of Maine, south and east of Lake Megantic.

It may be seen by reference to the accompanying map (Fig. 35) that these groups are in the form of belts, which have a general northeasterly trend and are approximately parallel. For convenience they may be designated as the Sutton, the Ascot, and the Lake Megantic belts.

Dimensions and Relations to Enclosing Rocks.—In all cases the deposits occur in, or in close association with, altered volcanic rocks, generally of the porphyry class. The country rock is always highly folded, and often twisted and contorted to a remarkable degree, and this deformation gives to the ore deposits their characteristic shape. In form the deposits are much flattened lenses, which lie in conformity with the foliation of the rock. They are arranged *en échelon* generally along zones of extreme foliation. The individual lenses seldom exceed twenty or thirty feet in width, and bodies of these dimensions would be approximately two hundred to three hundred feet in length, according to approximate generalization from observation of a considerable number of the smaller lenses, and from the experience of miners who have worked out many of such bodies. The third axis, that nearest the vertical, follows the dip of the foliation, but its length relative to the other axes is not easy to ascertain, even approximately, since it is only these lenses which lie wholly beneath the surface, and which have been wholly worked out that can give data of any value, although a depth of nearly three thousand feet has been reached. Opportunities for such observation are necessarily rare. Experienced miners seem agreed

that the dimension of these bodies in the direction of the dip is sometimes greater, at others less, than the horizontal axis, and some are of the opinion that it is generally greater.

The arrangement of the ore lenses *en échelon* is a matter of much importance in following the ore bodies. Thus in the Capelton district the miners have learned when a lens is exhausted to drift to the *right* to find the next. That is, that in proceeding along the strike towards the northeast, each succeeding lens appears on the southeast side of the previous one, *i. e.*, in the hanging wall, and in going towards the southwest the next ore body is to be looked for on the northwest, or in the foot wall. The dip here is from forty to seventy degrees towards the southeast.

The ore bodies correspond in their arrangement with the order of the hills of the district, and with the general structure of the Appalachian mountain system, in which each range when followed northward is succeeded by another lying to the east. It is evidently the same orthographic feature which gives the Atlantic coast its general northeasterly trend.

Though rarely, the ore bodies occasionally cross the planes of foliation of the country rock. They then have the aspect of veins running slightly oblique to the strike, or more rarely, to the dip of the enclosing rock. These vein-like masses are, however, of very limited extent, and are probably only the filling of local fractures between larger shearing planes. They are, perhaps, the better developed of the minor series of fracture joints.[1]

The walls of the ore bodies are not usually well defined, though one is usually more definite than the other. The ore, which consists essentially of chalcopyrite in pyrite, grows poorer towards the edges of the bodies where there are no definite walls, until the proportion of ore in the country rock becomes so small as to be imperceptible.

Origin of the Ore.—From the evidence at present available it can only be said that these ores were primarily brought in by the volcanics in which they are generally found; that the subsequent folding and shearing of the rocks developed planes of easier pas-

[1] J. B. Woodworth, *Proc. Boston Society of Natural History*, Vol. XVIII., p. 391, 1896.

sage in which the subterranean waters, leaching out the metallic minerals from the rock, deposited them by replacement. The better preserved wall on one side of the ore bodies may be due to the fact that the rock on that side of the shear plane was more highly fractured than on the other, as is often the case. The greater replacement would thus take place on the fissile side of the water-bearing crevice. After the first film of ore had been deposited, a protection was afforded by it for the rock face on which it was deposited and all further replacement was likely to occur on the more fractured side.

The common occurrence of chalcopyrite in crevices within the pyrite, and as a thin layer upon a joint face, seems to indicate that the chalcopyrite was introduced later than the pyrite. But of this there is not enough known as yet to speak decisively. Actual crystal replacement has not yet been observed.

Value of the Ores.—The average of a large number of assays of specimens from the south side of the Capelton hill, *i. e.*, from the Eustis and Capelton mines and other properties of the vicinity, showed the copper to range from 4 per cent. to 5 per cent., sulphur, 38 per cent. to 40 per cent., and approximately one ounce of silver to each unit of sulphur, with small amounts of gold.[1]

A number of assays of recent date from the north side of the same hill, from the Suffield, King and other properties, give a lower percentage of sulphur, but higher metallic values, especially of silver, which here seems to vary without regard to the sulphur. Gold is here commonly present to the amount of $2.00 to $4.00 per ton. As a very general statement the ores of this class of deposits may be said to carry 4 per cent. of copper, 35 per cent. of sulphur, near the surface, and at greater depths to yield uniformly 3 per cent. of copper, 45 per cent. of sulphur, three ounces of silver, and small amounts of gold.

Gold, which does not seem to be present in appreciable amounts at lower levels, is often an important factor near the surface. Alluvial gold occurs in many of the streams which run over copper-bearing rocks, and the surface rocks yield it in many places. At a depth of a few feet from the surface most such gold

[1] Dr. R. W. Ells, Geol. Survey of Canada, 1888–9, p. 53 K.

prospects have been abandoned, but in one or two notable instances they have developed into copper mines, the copper values increasing as the gold values declined.

Secondary Enrichment.—Although it has not yet been found possible to get information sufficiently definite and accurate to make a satisfactory comparison of the ores at different depths, there appears to be a slightly higher copper, and distinctly greater gold value, near the surface, than at a depth of a few hundred feet. This richer zone seems to be deeper but less well marked in the case of copper than of gold. The information available, however, is insufficient as yet to admit of safe generalization. At present it can only be said that there probably are such zones, that they are presumably due to secondary enrichment, and that any such enrichment has taken place from above, and hence by means of descending waters. The evidences that both the iron and the copper sulphides were deposited in their present position after the foliation of the country rock began have been already noted.

Source of the Copper.—The source of the copper and other metallic minerals seems undoubtedly to be the volcanic rocks. The principal deposits occur wholly within these rocks, smaller bodies, however, being not infrequently found along the contact of the volcanics with an overlying dolomite. In such cases the copper has evidently been deposited contemporaneously with the dolomite, which it more or less strongly impregnates for a distance of a few feet only from the volcanic rock.

It was recognized by Logan that the copper deposits were derived from the country rock.[1] But, on the assumption that the country rock was of aqueous origin, these were regarded by him as an excellent example of sedimentary mineral deposits. He thus summarizes his views:[2] "The evidence which has been presented in the description of the copper deposits of the Quebec Group, appears to show that the metal, like the iron, manganese, nickel and chrome, which so often accompany it throughout these rocks, was held in solution by the waters from which the sedi-

[1] "Geology of Canada," 1863, pp. 734–5.
[2] "Geology of Canada," 1863, p. 734 et seq.

ments of the period were deposited. By the agency probably of organic matter it was reduced to the condition of a sulphuret and precipitated with the sediments, either in a finely divided state, or more frequently, in small nodules, or patches, which became interstratified with the limestones, the slates, the diorites and the other rocks of the series. A subsequent action, probably contemporaneous with that which has metamorphosed and crystallized the rocks over a great part of their extent, dissolved out portions of the copper sulphurets from these beds, and in certain cases deposited them with quartz and various spars, in the fissures of the rocks, giving rise to the veins or courses which have been described.

"There appear to be in this region no facts to sustain the ancient notion of the connection of metalliferous deposits with eruptive rocks which are absent from great portions of the district."

With the knowledge that the country rock is eruptive, the above opinion becomes open to reconsideration. And since there seems to be no doubt that the copper has been derived from the country rock, these lodes can only be regarded as deposits genetically connected with volcanic rocks and the earlier view is thus completely reversed.

ON THE ORIGIN AND RELATIONS OF THE NICKEL AND COPPER DEPOSITS OF SUDBURY, ONTARIO, CANADA.[1]

ALFRED ERNEST BARLOW.

HISTORICAL RÉSUMÉ OF THE LITERATURE.

The literature on the nickel and copper deposits of the Sudbury mining district has already become so voluminous that it seems desirable before presenting an additional contribution to make brief reference to some of those publications which deal with the nature and origin of these justly celebrated ore-bodies. These deposits of pyrrhotite, with their unusually high content of nickel, and intimately associated chalcopyrite, are of importance, not only from the economic standpoint, but also from the point of view of science, as having furnished such strong presumptive evidence for regarding them, and their analogues in other places as igneous in origin, and as due to processes of differentiation in the original magma from which they and the associated eruptive have solidified.

In October, 1887, Mr. J. H. Collins visited the Sudbury region to examine into the extent and economic possibilities of the so-called copper mines. On June 6, 1888, he read a paper before the Geological Society of London "On the Sudbury Copper Deposits," in which he embodied the results of his examinations, which, however, seem to have been restricted to the area in the immediate vicinity of the Copper Cliff and Stobie Mines. An abstract of this paper was afterwards published[2] accompanied by two cross sections of the mines above mentioned, showing the geological association and position of these deposits. Mr. Collins mentions that the ore occurs in three forms, as follows:

1. As local impregnations of certain silicious and feldspathic

[1] Published by permission of the Director of the Geological Survey of Canada.

[2] *Quart. Jour. Geol. Soc. Lon.*, Vol. IV., 1888, pp. 834–838.

beds or belts of rock of clastic or fragmentary origin, in the form of spots, patches, and strings of cupriferous pyrrhotite.

2. As contact-deposits of the same mineral lying between the impregnated beds just mentioned and certain large interbedded or intrusive masses of diorite.

3. As segregated veins of copper-pyrites and highly nickeliferous pyrrhotite of secondary formation, filling fissures and shrinkage-cracks in the ore-masses of the second class.

There is much in this mode of occurrence to suggest that the copper occurring in the first mode was an original, or at least a very ancient constituent of the beds, while the richer masses of the second and third modes of occurrence have resulted from later segregations into openings produced either by the intrusion of the diorites or by internal movements of the rocks.

Mr. Collins further says that the following conclusions seem to be warranted:

1. The rocks immediately enclosing the ore deposits were originally, or at a very early period, pyritous and probably cupriferous.

2. The intrusions of igneous matter gave rise to lines of weakness along the planes of contact.

3. Subsequent fissuring and, to a certain extent, faulting, occurred at these contact-planes.

4. The filling-in of these fissures was mainly by solution from the pyritous and cupriferous material of the enclosing stratified rocks.

5. There is, in places, a pyritous breccia indicating a partial mechanical filling.

6. There is, in places, a concentration of mineral matter in those portions of the "country rock" which adjoin the more solid deposits occupying the fissures.

7. The formation of rich veinlets or "leaders" or ore within the masses has been the result of subsequent operations probably at many and very different times. These veins appear to occupy minor faults and shrinkage-cracks and to have been filled by segregation of more richly cupriferous material derived from the main masses of pyrites.

8. Abundant evidence of partial movements within the masses of pyrites is afforded by the numerous slickensides which are everywhere present.

This is probably the first detailed and authoritative utterance on the subject of the origin of these deposits. The conclusions have therefore been quoted at length in order to show that even at this early period strong insistence was made that the various agencies grouped together under the general term "secondary action" were the main, if not the sole determining cause of the present position and dimensions of the ore bodies. Mr. Collins, however, ignores any direct genetic connection between the sulphides and igneous rock, merely pointing out that the necessary fissuring of the associated rocks was doubtless produced by its intrusion. It is worthy of note that in the discussion which followed the reading of Mr. Collins' paper Mr. Atwood, who had been connected with the Dominion Mineral Company at the Blezard Mine, stated that "there was an abundant occurrence of diorite which in his opinion had brought up the metals."

At the Buffalo meeting of the American Institute of Mining Engineers, in October, 1888, W. H. Merrit[1] of Toronto, in reviewing the Minerals of Ontaria and Their Development, states that "the Sudbury ore occurs irregularly in large lenses and is also found disseminated through the diorite with which it has undoubtedly been brought up."

In the Summary Report of the Geological Survey of Canada for 1888 Dr. Bell[2] makes no mention whatever of the geological relations or origin of these ores but simply states that "the metals which give most promise are the copper and nickel deposits which have been worked for the last three years near Sudbury."

In the Summary Report for 1889 Dr. Bell[3] makes his first statement in regard to the genesis of these ore bodies in the following words: "These deposits may be described as 'stockworks' in which the vein structure is very obscure" and also that "it would not be surprising if they (the later olivine-diabase

[1] *Trans. Am. Inst. Min. Eng.*, Vol. XVII., 1888, p. 295.
[2] Ann. Rep. Geol. Sur. Can., 1887–88, p. 89, A.
[3] Ann. Rep. Geol. Sur. Can., 1888–89, p. 32, A.

dikes) should prove to have some connection with the concentration of the ore in these masses which may be locally enriched portions of certain ore-bearing belts."

In his account of the "Geology of Ontario with special reference to Economic Minerals," written by him as a member of the Royal Commission to inquire into the mineral resources of Ontario, the same writer[1] says that "the ore in this region is associated with an obscurely stratified greenstone and its mode of occurrence is apparently that of large masses and impregnations, having rudely lenticular forms and following fahlbands which are roughly conformable with the general stratification of the country rocks."

In the same publication he[2] expresses the opinion that "the general geological position of these ores is in diorite and more especially brecciated diorite" and asserts that "they appear to have been connected with longitudinal fissures and were of the nature of great brecciated veins or 'stockworks.'" Again he emphasizes the frequent association of the later dikes of olivine-diabase with the ores and ventures the prophecy that "it may be found on fuller investigation that they have had something to do with their enrichment at these places."

On March 6, 1891, the writer read a paper before the Logan Club of Ottawa "On the Nickel and Copper Deposits of Sudbury" which was published in June of the same year, in which appears the first definite statement affirming an igneous origin for these masses of sulphide material in the following words:[3] "The ores and the associated diabase were therefore in all probability simultaneously introduced in a molten condition, the particles of pyritous matter aggregating themselves together in obedience to the law of mutual attraction." In the same publication the author makes the significant statement which has since been amply proved that "the nickel is present in these ores as a distinct and separate sulphide like that of the vein and copper."

[1] "Min. Res. of Ontario," 1890, p. 231.

[2] "Min. Res. of Ontario," 1890, p. 435.

[3] *Ottawa Naturalist,* June, 1891, pp. 1–20; also Ann. Rep. Geol. Sur. Can., Vol. V., 1890–91; pp. 122–138, S.

In 1891 Dr. Bell[1] presented a paper to the Geological Society of America entitled "The Nickel and Copper Deposits of the Sudbury District, Canada," in which he adopts the hypothesis of the differentiation of these ores from a molten magma, thus materially altering his previous opinion which affirmed their secondary formation.

A little later in an article on "The Laurentian and Huronian Systems North of Lake Huron" the same author[2] states that: "although most of these ores appear to have separated themselves from a cooling magma, we find occasional evidence of subsequent modifying processes. Still there can be no doubt that the large ore bodies of this district were not originally deposited from aqueous solutions like the gangue and ore of ordinary metalliferous veins."

In the same year (1891) Dr. Bell[3] in his final report on "The Sudbury Mining District" again emphasizes his belief that these ores have originated primarily from a state of fusion.

At the Chicago meeting of the American Institute of Mining Engineers in August, 1893, S. F. Emmons[4] of Washington read a paper on the "Geological Distribution of the Useful Metals in the United States," in which he states his belief that the ore "was formed by concentration through percolating waters of the material originally disseminated through the rock in water channels formed by fault planes or zones of displacement."

W. H. Merritt[5] in the discussion of Mr. Emmons' paper again refers to the diorite as the source of supply of the ore, but states that, although the theory of the concentration of the ore bodies in the fused magma would not appear unreasonable, he yet considers that a secondary concentration must have taken place to explain the presence of some of the ore bodies. In support of this view he mentions the presence of thin films of native copper, the sharply brecciated horses of country rock cemented by the ore, and the bands of fluccan across certain of the deposits.

[1] *Bull. Geol. Soc. Am.*, Vol. II., 1891, pp. 135–136.
[2] Ann. Rep. Bur. of Mines, Ont., 1891, pp. 89–90.
[3] Ann. Rep. Geol. Sur. Can., 1888–90, pp. 49–51, F.
[4] *Trans. Am. Inst. Min. Eng.*, Vol. XXII., 1893, p. 70.
[5] *Trans. Am. Inst. Min. Eng.*, Vol. XXIV., 1894, pp. 755–756.

During the summer of 1890[1] the late Baron Von Foullon of the Geological Survey of Austria spent a few weeks in this country. As a result of his investigation he came to the conclusion that these ores were not deposited from solution but are of igneous origin.

During the summer and fall of 1893, E. Renshaw Bush,[2] while pursuing professional work, visited some of the more important deposits and afterwards published his observations in a paper called "The Sudbury Nickel Region." Mr. Bush in this paper states that "the chief features suggesting an aqueous origin are: (1) A prevailing tendency of the sulphides to occur along planes of contact, and fractures, cleavage planes and joints, and the impregnation of the rock in the vicinity of such planes. (2) The direct contact of some structurally different igneous or sedimentary rocks in certain localities of the mineral aggregates. (3) The impregnation of extensive areas of schistose strata in the neighborhood of greenstone masses.

Philip Argull,[3] in a paper entitled "Nickel, the Occurrence, Geological Distribution and Genesis of its Ore Deposits," read before the Colorado Scientific Society of Denver on December 4, 1893, advances his opinion that the nickel in all probability originally present in the diorite or diabase was leached out from these rocks by solutions potent to dissolve the nickel and concentrate it along lines or zones favorable to precipitation.

In a paper "On the Igneous Origin of Certain Ore Deposits" read before the General Mining Association of the Province of Quebec, Montreal, January 12, 1894, Dr. F. D. Adams[4] strongly endorses Professor Vogt's opinion that these ores are the differentiation product of a basic igneous rock. D. H. Browne,[5] in 1895, draws an analogy between a pot of matte, in which he found that the nickel and copper sulphides tended to separate, and the Sudbury ore bodies.

[1] *Jahr. der K. K. Geol. Reich.*, Vol. XLII., 1892.
[2] *Eng. & Min. Jour.* Vol. LVII., March 17, 1894, p. 246.
[3] *Proc. Col. Sc. Soc.*, Vol. IV., 1891, 92–93, p. 407.
[4] *Can. Min. Review*, February, 1894.
[5] *School of Mines Quarterly*, Vol. XVI., 1895.

In 1895 Professor J. F. Kemp,[1] a strong supporter of the theory of magmatic differentiation as regards these ores, gave a paper entitled: "An Outline of the Views Held To-day on the Origin of Ores," offering an explanation based on the laws of thermo-chemistry to explain the concentration of these sulphides of iron, copper and nickel.

In 1897 Dr. T. L. Walker[2] expressed himself as in agreement with Professor Vogt in regarding these ores as the direct product of the differentiation of the norite magma.

At the meeting of the American Institute of Mining Engineers held in Albany in February, 1903, Chas. W. Dickson[3] submitted a paper entitled "The Ore Deposits of Sudbury, Ontario." In the second part of this paper he adduces certain evidence in support of his opinion that all of the Sudbury ore deposits are of essentially and predominantly secondary origin. The evidence adduced is mainly based on examinations of the relations between the ore and rock minerals as seen under the microscope. His comparison of the Sudbury ore deposits with those of Rossland, B. C., and Ducktown, Tenn., is unfortunate, as all who have examined these last mentioned deposits are agreed that they are undoubtedly secondary and present little or no resemblance to those of Sudbury.

In the latest edition of Dr. Richard Beck's "The Nature of Ore Deposits," which is translated and revised by W. H. Weed (1905), the author concludes that "the segregation of the magnetic pyrite and copper pyrite in their present condition took place during or after the dynamic metamorphism of the gabbro rocks of that locality and not by means of a magmatic differentiation."

The hypothesis of magmatic differentiation as applied to these ores finds no stronger advocate than Dr. A. P. Coleman of Toronto University, who has perhaps devoted more time and attention to their study than any other geologist, and his latest expression in the report, which is daily expected, will no doubt contribute to greatly strengthen the position of those who entertain similar views.

[1] *Min. Industry*, Vol. IV., 1895, pp. 755–766.
[2] *Quart. Jour. Geol. Soc. Lon.*, Vol. LIII., 1897, p. 52.
[3] *Trans. Am. Inst. Min. Eng.*, Vol. XXXIV., 1903, pp. 2–67.

THE ORE-DEPOSITS.

THE NICKEL BEARING ERUPTIVE.

The nickel bearing eruptive may, for purposes of description, be considered under two divisions:

1. A basic portion: including certain gabbroid rocks, chiefly, at least, of the norite facies, with their derivative diorites, with which the nickel and copper bearing sulphides are immediately associated.

2. An acidic portion: comprising large areas of rock of granitic type, with well marked gneissoid structure, the prevalence and abundance of the graphic intergrowth of the quartz and feldspar, known as granophyre or micropegmatite, having suggested the name "micropegmatite" by which this rock is now generally known.

The line of outcrop of this intrusive sheet of norite traces an almost unbroken ellipse, northwest of Sudbury, with a major axis of nearly thirty-eight miles, lying northeast, and a minor axis averaging about fifteen miles. The width of exposure varies from one to four miles (including both the norite and the micropegmatite).

The least altered phase of the basic portion of the eruptive is represented by what may be referred to as "norite." The rock is sometimes called a "quartz-hypersthene-gabbro," but for general purposes the former name is preferred.

The microscopical examination shows the rock to be an eruptive of rather exceptional character and interest. It belongs to the general family of gabbros, but with distinct traces of, and, at times, well marked diabasic or ophitic structure. The prevalence and usual preponderance of hypersthene or enstatite, show its close affinity with the norites, while it contains, what is very exceptional for such a rock type, an abundance of original quartz. In fact, many specimens could be secured which contain nearly as much quartz as an ordinary hornblende granite. In some instances, noticeably at the Copper Cliff mines, a large quantity of micropegmatite or granophyre is present, the feldspathic constituent of this graphic intergrowth being usually plagioclase. Ex-

posures show a massive, medium to coarse-grained, dark-grayish, greenish-gray or brownish rock, which is often almost black in color on freshly broken surfaces. Scales of deep brown biotite are usually conspicuous, while the quartz is perhaps equally so, in very characteristic sapphire blue or purplish grains.

The orthorhombic pyroxene, either hypersthene or enstatite, shows a distinct approach to perfection of crystallographic outline, and, in many cases, was the first of the essential minerals to form. In occasional instances, the hypersthene is unaccompanied by a monoclinic pyroxene, as in some of the specimens collected in the vicinity of the Blezard mine. It is often by far the most abundant of the colored constituents, as at the Murray mine, where the diallage is only occasionally represented, while almost the whole rock mass is made up of hypersthene, in various stages of decomposition, the small and infrequent interspaces being occupied by plagioclase. The hypersthene is, as a rule, rather faintly pleochroic, although specimens from the vicinity of the Blezard mine, and from a railway cutting about one mile and a half northwest of the Murray mine, are very strongly pleochroic, rose red to pale yellowish-green. The enstatite is colorless in thin section and, in contradistinction to the hypersthene, exhibits little or no pleochroism. Both the hypersthene and the enstatite are very liable to decomposition, so that, in most cases, areas of this mineral are replaced by an aggregate of light-green, non-pleochroic, brilliantly polarizing fibrous or scaly serpentine (bastite). This alteration is often accompanied by the separation of minute grains of magnetite. In most cases, even the fresh individuals of hypersthene are bordered by a compact, strongly pleochroic, green hornblende which is doubtless an original constituent. This primary hornblende, likewise, forms borders on areas showing the complete bastitic alteration. In addition to this, there is undoubted secondary hornblende resulting from the alteration, first, of the bastite into actinolite, and this in turn to the ordinary type of green hornblende.

The monoclinic pyroxene, which is usually present in subordinate amount, is likewise frequently bordered by primary hornblende, and thus, the individuals of these two pyroxenes cannot

be distinguished from one another in specimens which have undergone any advanced decomposition. Sometimes both pyroxenes show the presence of the characteristic, minute, tabular interposition of schillerization products but, as a rule, these are absent. Olivine is present in small amount in the norite obtained from the Little Stobie mine, but most of it is altered to an aggregate of deep colored scaly serpentine, talc and magnetite. Biotite is an almost invariable constituent and is usually rather abundant in large plates and is undoubtedly of primary origin. The plagioclase is usually in broadly twinned, stout, lath-shaped or tabular crystals, whose frequent interlacing arrangement produces the characteristic, rude, ophitic structure. Separations by means of Thoulet's heavy solution, as well as the extinction angles, show that this plagioclase is labradorite.

Quartz and occasionally granophyre fills most of the irregular interspaces between the other constituents, although in the norite from the Creighton mine, microcline almost invariably accompanies this interstitial quartz. Apatite, magnetite, which is usually highly titaniferous, zircon and grains of pyrite, pyrrhotite and chalcopyrite are almost always present. These sulphides are distinctly of primary origin, and were among the earliest of the minerals to crystallize from the original magma, antedating even the magnetite, in some cases, for grains of pyrrhotite were noticed completely enclosed by the iron ore. The sulphides occur, for the most part, intimately associated with, and frequently embedded in the colored constituents, in much the same way as the magnetite, from which they can only be distinguished by the difference in color in reflected light. The pyrrhotite and chalcopyrite are often very intimately associated, so that they are extremely difficult of separation, even the smallest grains showing intimate intergrowths of these minerals with one another. These sulphides frequently occur in those portions of the norite which have suffered so little from dynamic metamorphism, that only an occasional dislocation of a plagioclase crystal is noticed in them, while they have been so little affected by hydrochemical agencies that such readily alterable minerals as hypersthene, enstatite, olivine and diallage are still plainly recognizable

in their specimens. The sulphide material, in such cases, is often not subordinate in amount, but is so abundantly disseminated as to characterize the rock, and justify the name of "pyrrhotite-norite" which is sometimes applied to it.

Although a considerable number of specimens were secured, representative of the comparatively unaltered norite, by far the larger proportion of the material collected consisted of a massive, usually coarse gabbro-diorite in various stages of alteration. Very few of these show even traces of dynamic metamorphism, and, as a rule, the ophitic structure, produced mainly by the interlacing arrangement of the plagioclase crystals, is quite undisturbed. The alteration is mainly due to hydro-chemical agencies and affects the pyroxenic minerals, decomposing these to a pale, yellowish-green serpentine, sometimes of the ordinary type, but usually of the bastite variety. Actinolite also results from the alteration of the pyroxenes. The compact borders of primary hornblende, often surrounding the original pyroxenes, are evidently made up of much more stable material, not having been affected by any of these changes. The areas formerly occupied by the pyroxene are, therefore, replaced by bastite or actinolite, the hornblende borders remaining unaffected, the individuals thus decomposed being referred to as uralite. No distinction can be drawn between grains which represent hypersthene or diallage, as both of these minerals apparently decompose to closely related, if not identical material. The labradorite is usually quite fresh, in tabular or broad blade-like forms, with a brownish color of varying shades, which is so prevalent in the norites. Occasionally it shows incipient decomposition to the usual saussuritic products, mainly sericite, but also epidote and zoisite. Biotite is always present and conspicuous in large plates with strong pleochroism. It is sometimes intergrown with the hornblende and has also undergone considerable "bleaching." It usually contains comparatively large irregular grains of magnetite. Quartz is always present, and sometimes abundant, filling up the irregular interspaces between the other constituents. Highly titaniferous magnetite and apatite are also always present, but in small amount, while the pyrrhotite and chalcopyrite vary in amount,

from occasionally disseminated grains to such quantities as ensure the use of the mass as an ore of nickel and copper.

In addition to the norite and diorite, a more acid rock of granitic composition and prevailing gneissoid structure occurs, which cannot be separated genetically from the more basic portion with which the sulphides are more directly associated. This rock has usually been referred to as "micropegmatite" a name first suggested by the late Professor G. H. Williams.[1] There is no sharp line of demarcation between the acidic and basic portions of the nickel bearing eruptive, but the change, though gradual, is usually sharp enough to enable a boundary to be placed between these two types, with tolerable accuracy. Outcrops of this rock are evenly banded or foliated, with a distinct strike and dip, usually porphyritic, weather a pale reddish or grayish color and are frequently intersected by irregular and often intricate vein-like masses of quartz, evidently of pegmatitic origin. On freshly exposed surfaces, the rock is usually dark colored, with abundantly disseminated, small, reddish or yellowish phenocrysts of feldspar. Orthoclase is often present in considerable amount, and towards the outer edge of the mass is the predominant feldspathic constituent, but plagioclase (oligoclase or oligoclase-andesine) is usually more or less abundant. Microperthite and microcline are also often present, but in subordinate amount. Much of the feldspar is somewhat turbid, owing to decomposition. Biotite is the prevailing ferromagnesian mineral and much of it is "bleached" and altered to chlorite. It is usually in small, irregular, tattered scales and plates, arranged in narrow, approximately parallel bands, gently curving around and among the larger phenocrysts of feldspar. The abundance of the biotite, and its frequent alteration to chlorite, give the prevailing dark color to the rock on fresh surfaces. The transition type between the micropegmatite and the norite, shows a varying proportion of hornblende, which mineral, as a general rule, diminishes in amount in passing outward from the norite, although certain bands of relatively greater basicity show an appreciable amount of this mineral, even at a considerable distance from the line of

[1] Ann. Rep. Geol. Sur. Can., Vol. V., 1890–91, Part F, p. 78.

junction. One of the most noteworthy points, in connection with this gneissoid rock, is the prevalence and abundant development of micropegmatite or granophyre, and also the fact that plagioclase and quartz are most frequently the component minerals forming this graphic intergrowth. The micropegmatite, together with the bisilicate material, chiefly biotite or chlorite, and sometimes hornblende and accessory epidote, ilmenite and sphene, form a groundmass in which the comparatively large phenocrysts of feldspars, chiefly plagioclase, but sometimes also orthoclase and microperthite, are embedded. The granophyre or micropegmatite very often stretches out in various directions from a central portion or body, made up of well twinned and rather sharply bounded crystals of plagioclase. The effect of pressure is very noticeable in all the thin sections, not only in the strain shadows, but also in the dislocation of the feldspar individuals and the abundant development of the fine interstitial quartz and feldspar.

On the first geological map this micropegmatite was included with, and colored as, a part of the Laurentian, the reddish color, gneissic structure, and general behavior being the main factors which determined this classification.

The variations in the chemical composition, marking the transition from the norite to the micropegmatite, is well illustrated by a series of analyses made by Dr. D. T. Walker[1] from specimens obtained from the Blezard mine crossing. The specimens range from south to north, from I. to V. Analysis No. IV. is by Mr. C. B. Fox.

	I.	II.	III.	IV.	V.
SiO_2	49.90	51.52	64.85	69.27	67.76
TiO	1.47	1.39	.....	0.78	0.46
P_2O_5	0.17	0.10	0.24	0.06	0.19
Al_2O_3	16.32	19.77	11.44	12.56	14.00
Fe_2O_3	....	0.47	2.94	2.89	.....
FeO	13.54	6.77	6.02	4.51	5.18
CaO	6.58	8.16	3.49	1.44	4.28
MgO	6.22	6.49	1.60	0.91	1.00
MnO	trace	trace	trace	trace	trace
K_2O	2.25	0.70	3.02	3.05	1.19
Na_2O	1.82	2.66	3.92	3.12	5.22
H_2O	0.76	1.68	0.78	0.76	1.01
Totals	99.03	99.71	98.30	99.35	100.29

[1] *Quart. Jour. Geol. Soc. Lon.*, Vol. LIII., February, 1897, p. 50.

NOTES ON THE ORIGIN OF THE SUDBURY ORES.

DAVID H. BROWNE.

In examining the various theories as to the genesis of the copper nickel ores of Sudbury, I have naturally been led to consider them from an economical and metallurgical standpoint. The relation of the ores to included rocks, the variation in composition of the ore with reference to their place in the ore body, and the changes in the ratio of copper to nickel contents; such points as these have a distinctly economic bearing. From such study of the ores certain ideas have crystallized and are here presented for their bearing on the geology of the ores.

In explanation of the Sudbury ore deposits two theories have been offered. The first, that of segregation from a molten magma finds the support of the provincial and dominion geologists and others who have studied the subject on the ground. The second, that of deposition from aqueous solutions appeals to those who study the ore deposits by analogies, with the aid of text-book descriptions and microscopic rock sections.

Briefly stated, the magmatic theory supposes the instrusion of immense masses of molten or semi-molten material from which segregated in cooling the ore bodies and their enclosing and surrounding rocks. The aqueous theory assumes the existence of nickel in the greenstones or diorites, and supposes it to have been concentrated by leaching waters along zones of shearing and faulting.

The arguments in favor of the igneous theory may be summarized as follows: There is a gradual transition from the acid or granitic rocks to the basic or dioritic rocks, so that one class appears to merge into the other. There is also a gradual transition in the ore bodies from rock carrying a little ore to ore carrying a little rock. The ore bodies contain magnetic iron oxide which elsewhere in Ontario is an admitted constituent of igneous

rocks, and finally the mineral shows under the microscope very little evidence of secondary action.

The arguments *per contra* are that the diorites and greenstones in the neighborhood of the ore do contain small amounts of nickeliferous pyrrhotite, that there is a sharp line of contact extending for many miles between acidic and basic rocks, that along this line is much evidence of distortion and crushing, and that a microscopic examination shows the sulphides penetrating crystals of silicates in such a way as to suggest the replacement of silicates by sulphides.

Such, without going into detail, is as much as the layman grasps of the two arguments. The metallurgical relations of the ores are upon the side of the magmatic segregation theory, and some of these relations may here be explained.

In the first place, the ores are remarkably monotonous, consisting as they do of pyrrhotite, chalcopyrite and pentlandite. The composition of these ores at least as they occur at Sudbury, is:

	Chalcopyrite.	Pyrrhotite.	Pentlandite.
Fe	30.5	61	30
Cu	34.5	—	—
Ni	——	—	35
S	35	39	35

Practically speaking, there is no pyrite, marcasite or any other sulphide found in the great ore bodies.

Secondly, we do not find in the Sudbury deposits any replacement minerals, any chalcocite, cuprite, malachite or chrysocolla, such as are common in copper ores in Montana and Arizona, nor do we find any nickel silicates or hydrated nickel minerals such as are found in North Carolina and Oregon. Any such secondary minerals that may have come from this district are of extreme rarity; practically speaking, they do not exist. The ore from all the great deposits, Copper Cliff, Evans, No. 2, Stobie, Frood and Creighton, is entirely pyrrhotite, chalcopyrite and pentlandite, with more or less intermingled breccia of norite rock.

Thirdly, the ore deposits are water-tight. By this I mean they contain no cracks, seams or zones of enrichment, nor do they show any evidence of lines of weakness along which ascending

or descending waters might have entered. The ores fill the deposit space absolutely. There are no vugs, no drusy cavities, no crystalline formations such as one finds elsewhere from the action of water. A crystal of any sort is the rarest possible occurrence in the Sudbury ores.

Fourthly, the mines are as a rule dry, and what little water is encountered is surface water.

Fifthly, water has little or no effect upon the raw ore, and the mine water, even on the lower levels, is so pure that it can be drunk by the men. Even in old workings water appears to have very little action on the mineral, and the only stain which is found upon the walls of the open pits is due to leaching of the gossan.

Sixth, there is very little gossan on the deposits. They weather very slowly. Since glacial times many deposits have remained untarnished and with their bright glacial polish intact. Even on exposed hillsides the gossan is very thin and the ore shows only a few inches of surface tarnishing.

These points seem to prove that the ores once formed were not removed, changed, or in any way disturbed by surface action.

Admitting that some of the smaller mines, such as the No. 1, the Vermilion and the Victoria and a few outlying deposits do show somewhat vein-like structure and slickensided edges, it must be admitted also that these small deposits are outside the main ranges and do not represent the large ore masses. Further, it is quite possible that this vein-like structure may have been produced by mass movements of the ore bodies or their surrounding rocks after, and not before, the segregation of the sulphides. Any data drawn from such small mines as these are apt to be very misleading since these represent a different type of deposits from the main ore bodies.

On the other hand, while the ore bodies show little or no evidence of secondary enrichment or replacement, any one who has had the slightest familiarity with the Sudbury ores, knows that copper tends outwards toward the rock, and nickel tends inwards toward the center or at least toward the hottest part of the deposit. If the ratio of copper to nickel is one to two in the ore,

it rises to one to one in the norite rock picked out from the ore. The following shows this tendency of copper to collect around the edges of the deposit and thereby to increase the copper ratio in the rock:

RATIOS OF COPPER TO NICKEL.

No. 2 Mine	Ore,	100	parts	Cu	to	187	parts	Ni.
	Rock,	"	"	"	"	89	"	"
Creighton	Ore,	"	"	"	"	340	"	"
	Rock,	"	"	"	"	253	"	"
Evans	Ore,	"	"	"	"	114	"	"
	Rock,	"	"	"	"	43	"	"

While it may seem an absurdity to argue a similarity between the deposition of these ores and the manner in which the copper-nickel sulphides segregate in a matte pot, yet there is a striking analogy between these two. In the *School of Mines Quarterly*, Columbia College, for July, 1895, I published a series of diagrams showing how in a pot of molten matte the copper tends to move outward toward the cooling sides, while nickel is concentrated inward to the center. Eleven years have served to confirm this general impression that the copper and nickel in the ore bodies have followed the same laws and distributed themselves in accordance with this viscosity and their fusion points. Sometimes the change from a copper ore on one side of a deposit to a nickel ore on the other side is very noticeable.

The most striking change in ore ratio which I have yet seen occurred at the Crean Hill mine. In diamond drilling across the deposit from foot to hanging wall and through several included rock masses, all of which with both the foot and the hanging wall were of norite, the ore changed with remarkable regularity from copper ore on the foot to nickel ore on the hanging wall. Taking the per cent. of copper at any analysis as 100, the amounts of nickel in relation to the copper in crossing the vein were:

RATIOS OF COPPER TO NICKEL IN THE CREAN HILL MINE VEIN.

Footwall,	Ore	100	Cu	to	12	Ni.		
Rock intrusion,								
	Ore	"	"	"	11	"		
Rock,								

Rock,	Ore	"	" 16	"
Rock,	Ore	"	" 18	"
Rock,	Ore	"	" 54	"
Rock,	Ore	"	" 97	"
Rock,	Ore	"	" 340	"
Rock,	Ore	"	" 1250	" hanging wall.

Another diamond drill hole on the same vein showed the ratio changed from 100 Cu to 21 of nickel on the foot wall to 100 Cu to 413 nickel on the hanging.

While this segregation of copper and nickel holds true in the mines, its effect on the ore body is not as great as might be expected. The ore bodies are very large. The method of mining is such that the ore is taken out from all over the deposit at the same time. In this way, and for this reason, the analysis of the ore from any mine varies very slightly from month to month.

Another point of metallurgical interest is the composition of what might be called the "residual rock" in the ore. If a green ore be melted down without chemical change, we obtain the sulphides free from the enclosed rock and the rock free from the surrounding ore. In so doing on a furnace scale we obtain a highly aluminous slag. The composition of this is best studied by calculation from analysis of the ore.

CREIGHTON ORE ANALYSES.

Cu	1.77	SiO_2	10.10
Ni	5.62	Al_2O_3	6.85
Fe	44.68	MgO	1.40
S	27.48	CaO	1.19

Figuring the sulphides as chalcopyrite, pyrrhotite and pentlandite and recalculating the other elements to 100 per cent., we get from the above ore the following residue:

SiO_2	35.58	MgO	4.00
FeO	32.06	CaO	4.18
Al_2O_3	24.13		

Take No. 2 mine ore and calculate the residual rock in the same way.

No. 2 Mine Ore.

Cu	1.33	S	27.48
Ni	3.55	Al_2O_3	7.20
Fe	44.30	CaO	.15
SiO_2	11.82	MgO	3.08

This leaves residual rock containing:

SiO_2	41.7	CaO	.5
FeO	21.1	MgO	10.8
Al_2O_3	25.4		

This, as in the Creighton ore, is an extremely aluminous and sticky residue, such as would be expected to remain behind from the movement of a segregating magma. If we take the aqueous theory we must suppose the leaching water to have attacked a norite rock, and removing from it certain elements, replaced them by sulphides. The analyses of diorite shows 47 per cent. silica. The Creighton ore itself contains about 10 per cent. silica. This amount of removal will not in any way account for the amount of mineral introduced, nor for the exceptionally aluminous character of the residual rock. It is much easier to conceive that this residue is the remainder or dregs of the magmatic separation.

There was published in the quarterly *Journal of the Geological Society* of London, Vol. III., the following series of analyses by Dr. T. L. Walker of the rocks obtained along the Blezard mine crossing:

	I.	II.	III.	IV.	V.
SiO_2	49.90	51.52	64.85	69.27	67.76
TiO_2	1.47	1.39	....	.78	.46
P_2O_5	.17	.10	.25	.06	.19
Al_2O_3	16.32	19.77	11.44	12.56	14.00
Fe_2O_3	....	.47	2.94	2.89	....
FeO	13.54	6.77	6.02	4.51	5.18
CaO	6.58	8.16	3.49	1.44	4.28
MgO	6.22	6.49	1.60	.91	1.00
K_2O	2.25	0.70	3.02	3.05	1.19
Na_2O	1.82	2.66	3.92	3.12	5.22
H_2O	.76	1.68	.78	.76	1.01
	99.03	99.71	98.31	99.35	100.29
Sp. Gr.	3.026	2.832	2.788	2.724	2.709

This shows an increase in bases and a decrease in acid throughout. A still more basic rock is the norite which lies in the ore, in some cases surrounding, in other cases surrounded by the sulphides. This norite analysis is as follows:

	Creighton Norite.	No. 2 Norite.
SiO_2	47.70	47.82
FeO	12.35	12.09
Al_2O_3	15.23	16.57
CaO	8.72	7.32
MgO	6.55	6.62
Cu	.10	.15
Ni	.30	.30
S	.25	.25

A still more basic rock than this is the "residual" rock entangled in the ore. We have thus a series ranging from the residual rock through the norite and diorite up to the pegmatites and granitic rocks.

If we examine the relation of acid to base in these rocks by calculating the amount of oxygen present in the silica and the total amount of oxygen present in all the bases, we find a regularity that is more apparent than a simple examination of the analyses would indicate of the rocks in Walker's table, the two most acid rocks, IV and V are practically alike in oxygen ratio. The other arrange themselves in the following series:

	Per Cent. Oxygen in Silica.	Per Cent. Oxygen in Bases.
V	36.11	10.99
IV	36.92	10.17
III	34.56	10.67
II	26.59	15.37
Usual Norites	24.5	17.00
Residual Rock	18.84	21.86

Looking at these from a metallurgical standpoint, the fusion point of these rocks increases in passing outward from the norite to the acid granitic rocks. This is another way of saying that the acid rocks are those which would naturally chill and solidify

first either from a molten mixture or from a saturated and highly heated rock solution, so the diorites and norites, being more basic and easier molten or dissolved, would be the last to separate out as rock masses, while the sulphides would segregate naturally toward the basic and away from the acid series.

This shows that as the ore itself has segregated and arranged itself in accordance with the fluidity and migration velocity of the copper and nickel sulphides, so the rocks appear to have segregated or crystallized in order of their acidity.

A point that has been much overlooked by all geologists is the role of the conglomerates or volcanic breccias which occur in the neighborhood of the ore bodies. These were undoubtedly forced up from below and have filled large areas between the diorites and the granites. They contain numerous angular brecciated fragments of the surrounding rocks, and in addition often show sulphide minerals. These rocks in their general appearance are not unlike the ore bodies save that the ore is scattered. Occurring as they do in the immediate vicinity of the ore, and carrying much the same angular breccia as the ore does, it seems to me that both must have had a similar origin. The enclosed fragments of granite and diorite embodied in this conglomerate breccia cannot be adduced as proof against its igneous origin, and yet the occurrence of the same fragments of granites and diorites in the ore masses are often appealed to as proof against the magmatic origin of the ores.

There is in truth much vagueness as to what constitutes a magma. Van Hise's clear statement that at certain conditions of heat and pressure solids and liquids are miscible seems to me to afford a clue to the situation. According to this a magma may be at the same locality and time several different things varying with the depth and pressure. It may be near the surface an intensely heated molten rock mass holding water in solution, and at greater depths may be an intensely heated solvent holding rock in solution. Conceived in this way, it is quite possible to suppose a slowly cooling mass in which minerals and metals can arrange themselves according to Soret's principle, and at the same time we can suppose the pressure of solvents enough

to remove or replace certain minerals and impregnate their skeletons with sulphides as shown by sections examined microscopically.

It may be said in general that aqueous theory does violence to the whole present condition of the country, and finds no local support except among those who have studied extreme conditions in small veins on the outer edges of the nickel belt. In such cases even the most ardent disciple of the magmatic theory willingly concedes local and secondary alterations. An attempt to make these same conditions apply to such massive deposits as the Stobe, Creighton or No. 2 is an attempt to disregard the present evidence of the senses. In these large deposits we see an almost exact duplication of the structure of the admittedly igneous conglomerates which accompany the ores. We see the same twisting and distortion, and the same breccia of included rock masses. We note also the absence of any leaching waters, or of any channels or seams through which leaching waters could in the past have acted. We find no traces in these large bodies of crystallization or secondary mineralization, but on the other hand, we note considerable evidence of segregation not only in the sulphides, but in the accompanying diorites and granites. Such evidences as these growing gradually year by year have given the theory of magmatic separation a strong hold on our local geologists, as the true explanation of the genesis of these ore deposits.

DISCUSSION

This department has been established by the editors in order to afford to those interested in questions relating to economic geology an opportunity for informal discussion. Contributions are cordially invited either in the form of discussion of more formal papers appearing in earlier numbers or bearing upon matters not previously treated. Letters should be directed to the Editor, South Bethlehem, Penna. The full name of the author should be attached to all communications.

THE UNIVERSITY TRAINING OF ENGINEERS IN ECONOMIC GEOLOGY.

Sir:—Although there can be no one solution of the problem of how and what to teach in a course in Economic Geology since conditions in different institutions often differ widely, yet a discussion of the problem as it presents itself in various institutions should be mutually helpful to those giving such instruction. To such a symposium the writer offers the following contribution.

Institutions may with respect to such work be differentiated into two classes. One, either from purpose in founding or from local considerations of clientage and character of natural resources locally prominent, devotes itself mainly to some line or lines largely determined by these local conditions. For such institutions the problem of the relative stress to be laid on various topics becomes easy of solution. Local conditions govern; for such work is not designed to be well rounded. Building stone would be a more important topic in Maine than in Louisiana, while in neither would coal and iron be of such importance as they would be in Alabama or Tennessee.

Such cases are special ones and are more capable of satisfactory solution than the more general one presented by the second class of institutions where the aims of the institution and the clientage are such that local considerations have but little weight in framing the course. The course in these should be a more evenly bal-

anced one than in the former case. Since a large amount of the work is done primarily by the student this need not prevent as much differentiation of work among individuals to suit each one's peculiar needs or predilections as may be thought by the instructor desirable to be given in a first year's course in economic geology.

In planning such a course the first problem is to decide what material to include and on what principle to arrange it. If three hours per week for a year be given, it will be possible to give fair treatment to most of the topics that one would ordinarily include in a general course in economic geology but would not permit of exhaustive details in the treatment of any one topic. In the arrangement of the subject matter for such a course the writer's experience has been that of the two broad divisions of subject matter the non-metallic materials should precede the metallic because of the greater simplicity of their treatment and their greater economic importance as well as the fact that many of them are more familiar either by occurrence or by use than the raw metallic materials usually are.

By such an arrangement a further advantage is gained in that in treating certain topics such as underground waters and their circulation and the disintegration of rocks and formation of soils much may be given that will be of use later in the discussion of the origin of ore deposits.

Within the group of non-metallics, the writer feels that the treatment of cements, clays and soils must be more or less unsatisfactory in a general course since each is a large topic in itself. Such topics would more appropriately and satisfactorily be made the subjects of special courses to be given after a general introductory course and detailed treatment of any topic among the metallics would be similarly placed.

The writer has not yet found or made a classification of non-metallic materials that is entirely satisfactory and his experience is doubtless that of others. It is difficult to group according to any logical principle the heterogeneous topics that must be included in such a course. A classification based largely on chemical composition of material but modified by industrial use and

by mode or origin has more nearly given coherence and sequence to the topics discussed than anything else.

In beginning work on metallic materials students should be required to become familiar with the views of Pošepny, Van Hise, Lindgren, Kemp and others who have made noteworthy contributions to our theories of the origin of ore deposits. For this purpose as well as for other reading in both metallics and non-metallics the writer finds the preliminary form of the papers published by the American Institute of Mining Engineers especially helpful. These papers are classified by subjects and some of the longer and more important ones are separately bound for student use.

An assignment of such material for parallel reading is made each week. The amount read weekly by each student varies with the topic assigned, but is usually from fifty to one hundred and fifty pages. If a student wishes to pursue a given topic further he is encouraged to do so and is allowed to omit an equivalent of other reading assigned in subsequent weeks.

Besides such library work on assigned papers, the student must be taught how and where to find for himself the literature on any given subject and how to use it after he has found it. Good practice consists of the preparation of abstracts of important papers, of bibliographies of a subject or a locality, or of compilations of localities and other facts of occurrence, production, and use and their graphic representation as far as may be by means of maps and diagrams.

The method of instruction should include both lectures by the instructor and laboratory, library and field work by the student. In the laboratory the student should become familiar as far as is possible with typical examples of the materials under discussion and study them if possible in relation to the process of or steps in their preparation for use. This demands of course a working collection or museum of economic geology. For field work the summer vacation period must be utilized.

Since such a course must be preceded by work in general geology, mineralogy and chemistry, at least, it cannot be put in the early part of a course in mining engineering. Since opportunity

should be given after taking such a course for specialization along any line that may be desirable it should not be placed at the last of the course. In a four years' course possibly the second or preferably the third year would seem the place best suited for such general economic work.

L. C. GLENN.

Sir:—The unprecedented expansion of the mining industry in recent years, the tendency toward concentration of control in a few hands, and the accompanying changes in methods of mining, extraction, and transportation of the ores have required a differentiation and specialization of the technical help necessary for the mining, extraction and transportation of the ores. The versatile mining engineer who, if called upon, will open up a mine, install machinery, run a concentrating plant, build a railway, or make a geological report, with excursions into other technical branches, is as ubiquitous as ever, but his activities are becoming less diversified, and a part of his work is passing into the hands of specialists in one or more of these several lines of work, such as the civil engineer, the mechanical engineer, the metallurgist and the geologist. These specialists may or may not know some of the other branches necessary to mining. It is highly desirable that they do know them. But their essential qualification must be thorough training in the fundamentals of their particular lines; the application of these principles to mining can, if necessary, be largely acquired in the local field of work. On the other hand, the man who has acquired a knowledge of the applications of his specialty to mining without a thorough grounding in the principles can scarcely supply this deficiency in later years and is permanently handicapped in the development of new methods to meet the constantly changing conditions. Managers of some of the largest mining enterprises are beginning to insist on thorough fundamental training in their technical help even to the point of taking men whose training in applied mining and allied subjects has been trivial. They reason that experience will soon give them enough of the applied branches to meet their immediate needs, while experience will not give them the fundamentals.

The economic geologist or mining geologist in demand and

likely to be more in demand in the future, is the one who knows geology in all its aspects,—stratigraphic, physiographic, structural and metamorphic. The more he knows of mining in addition the better, but such knowledge will not take the place of knowledge of geology. The so-called geologist with a varied knowledge of mining and mining costs but without solid training in geology has more than once brought discredit to the profession by his "geological conclusions." In teaching economic geology, then, the emphasis should be upon geology rather than upon distribution, values, extraction, and uses of ores, although these subjects should be covered. As now taught in some of our leading schools and discussed in most of the text books, emphasis is placed on the commercial and geographic features to such an extent that the subject is not far different from commercial geography. An opposite tendency, to place most emphasis on geology, is now becoming manifest in several of our institutions. An illustration the writer knows best is the course in economic geology at the University of Wisconsin, which is designed primarily for students who have had courses in general, physiographic, historical and field geology and in mineralogy; also preferably in structural and metamorphic geology. Partial exceptions are made in individual cases. The course in economic geology, running through the year, is prefaced by a two months' review of the principles of structural and metamorphic geology. Thereafter the class work is devoted entirely to the geology and genesis of the ores. The necessary knowledge of distribution, values and allied features is gained by the students in considerable part, though not altogether, outside of class work by referring to original sources and platting this information for each of the economic minerals on base maps of the United States. Such a course is necessarily open only to the few and moreover usually involves graduate study. It is adapted to the training of men who plan to make economic geology a profession or at least an important part of their work. It might be argued that a more elementary course should be offered for those going into other professions or desiring it for its educational value. This may be desirable, but without basis of geological principles the elementary

course tends to become largely statistical. Should not such a course be called a statistical or geographic course and the name economic geology reserved for the more advanced course in which the emphasis is on geology rather than statistics and geography?

C. K. LEITH.

WHAT IS A FISSURE VEIN?

Sir:—As far as I know the credit of inventing the phrase "True Fissure Vein" belongs, not to the literature of ore deposits, but to composition of a far more imaginative order, namely the prospectuses of the promoters of "wildcat" mining companies. These gentlemen found the phrase a good one, experience having shown them the necessity of impressing upon the public the fact that some, at any rate, of their statements were true, and their acquaintance with truth being on a par with their knowledge of fissure veins, they saw no reason why the ingenious phrase should not be used. It appears to have originated before the auriferous deposits of Witwatersrand or of Western Australia were known, when the great bulk of the world's supply of reef gold, and indeed of most other metals was derived from fissure veins; at the same time it was known that fissure veins did persist in depth, whilst some other deposits, such as gash veins and pockets, did not, so that the statement on a prospectus that the deposit, towards the purchase of which the public was being invited to subscribe, was a "True Fissure Vein" seemed to carry with it a sort of implied promise that the riches which it contained would continue down to an indefinite depth.

From the scientific point of view I see as little need for stating that a fissure vein is a true fissure vein as I should for saying that a seam of coal is a true bed. That the term fissure vein itself needs defining, no one will I think deny, as it is used by different writers in such ways as to include very different things. Part of this confusion is undoubtedly due to the fact that the Germans, who were the pioneers in the study of mineral deposits and from whom we for many years derived all our knowledge, have only the one word "Gang" to describe those very different occurrences, the igneous dyke and the mineral vein. Personally I hold

that the correct method in such cases is to commence at the beginning, and taking the mineral vein to be one class of mineral deposits, to first of all lay down a definition of what constitutes a mineral deposit. My definition of the latter is as follows: "A mineral deposit is a portion of the earth's crust that contains mineral of intrinsic value in such quantities as to be workable under suitable conditions." From this I exclude rock masses, such as building stone, etc., which are essentially the object of quarrying. Such mineral deposits may be classified, if desired, by the nature of their contents, a suitable classification being for example the following: I., fuels; II., ores; III., salts (barytes, fluorspar, phosphates, borates, etc.); IV., gems (including semi-gems). If this definition of mineral deposits and their contents be accepted, the ordinary dyke is necessarily excluded from the class of mineral veins because it is not a mineral deposit. Obviously, however, a dyke containing some valuable mineral must be classed as a mineral deposit; in this case, however, I class it not with veins but under the head of "Dissemination (of valuable mineral) in igneous rocks." I therefore uphold the correctness of our English nomenclature which discriminates sharply between dykes and veins; the former are fillings of fissures injected in the molten state, and the minerals they carry are those which crystallize out from molten magmas, whilst the latter are the result of the action of mineral solutions. In the former the production of the fissure may be, and probably in many cases has been simultaneous with the eruption of the molten matter, and the rate of filling must have been comparatively rapid; in the latter case the formation of the fissure must have long preceded its filling, which must have been a comparatively slow process. I therefore define a fissure vein as a "mineral deposit occupying a pre-existing fissure in the earth's crust, and which has been introduced otherwise than in a molten state."

I distinguish fissure veins from bedded veins, which have been deposited in a plane of weakness between adjoining strata; how far the gash vein should be considered a separate class is to my mind doubtful; it might be looked upon as a fissure vein of limited extent, and confined to one particular type of fissure, thus

making it a subclass of the fissure vein class; or it might be looked upon as a special form of irregular deposits (masses) in soluble rocks. Either classification seems to me to be genetically and economically sound.

The most difficult question respecting fissure veins arises when we have to deal with deposits produced by the mineralizing action of solutions which traversed a fissure, but which have been formed by the metasomatic action of these solutions upon the walls of the fissure and either in small part or not at all by the deposition of mineral within the fissure. It would evidently be quite logical to class that portion of the deposit which fills up the fissure as a vein and that portion which is formed by the altered walls as a metasomatic deposit. This is, however, somewhat cumbersome on the one hand, and on the other there are very few veins, if any, that have not been produced in part at least by metasomatic action. Any miner who has had to struggle hard to keep up the walls of the vein he is working, will find it hard to credit that this same fissure can have stood open during the long period that must have been needed for the formation of the vein. I hold that such fissures must have been filled loosely with fragments derived from the walls, which kept the latter apart and yet at the same time afforded an easy passage to the mineralizing solutions, which later attacked and removed the material of the shattered fragments at the same time that they deposited the vein-stuff, so that the formation of the vein itself was essentially a metasomatic process. Furthermore, even though the deposit be not wholly confined within the fissures it must not be forgotten that the fissure was, after all, the predisposing cause, to the presence of which the vein owed its existence. I therefore prefer to class all such deposits, which owe their origin to the pre-existence of a fissure, as fissure veins. If it were possible, it might perhaps be advantageous to discriminate between deposits filling fissures and those due to metasomatic action upon its walls, but I am by no means sure that the advantage would be great. A true natural system of classification of mineral deposits, such as we meet with in the organic kingdom, is obviously impossible, there being no such development of one group from the other as renders such

a classification possible. The only object in classifying mineral deposits is to facilitate their study by bringing together such deposits as have certain properties in common, and it matters little which properties we select so long as the study of the subject is really simplified. Different workers will naturally select different modes of grouping, and it seems probable that we shall have many different systems of classifying mineral deposits for a long time to come.

HENRY LOUIS.

NEWCASTLE-UPON-TYNE,
ENGLAND.

Sir:—There are probably relatively few veins of the character usually designated as fissure veins that have not been more or less affected by replacement of the vein walls, and the term is quite commonly applied to deposits in which the original fissures have been modified by subsequent action of this nature. The definition should, therefore, take that fact into consideration and be so worded as to cover it, and the question under discussion has apparently reached the point where a simple definition is wanted rather than the expression of a geological condition.

The definition given by Doctor Raymond, namely, "A mineral mass occupying a fissure in the earth's crust" tends to restrict the meaning, and may be criticised as limiting it to the filling of a pre-existing fissure only; while that by Lindgren, quoted by Mr. Ries, covers the facts admirably, but is rather a description than a definition.

It is natural for us to see merit in our own inventions, hence the writer ventures to suggest a reply once used by him when asked the question under consideration: "A fissure vein is a deposit of mineral within a plane or zone of fracture or faulting."

WALTER S. KELLEY.

WHAT SHOULD APPEAR IN THE REPORT OF A STATE GEOLOGIST.

Sir:—The answer to your question "What should appear in the report of a State Geologist?" lies, as it seems to me, in a correct conception of what a state geological survey should do. The

report, or reports, should contain the results of the survey presented in convenient and accessible form. An examination of the laws governing a number of state geological surveys indicates that they are designed to carry on studies of the mineral resources of the states with a view to (*a*) exploration, and (*b*) exploitation. Legislators in appropriating money for the foundation and maintenance of such bureaus evidently have in mind the strictly utilitarian purpose of stimulating development of the natural resources of the state. When the educational phases of the work are mentioned in the governing act it is usually incidentally only. It is the duty of all officers to carry out the purpose of the law and to loyally observe its intent. The state geologist should therefore shape his work to the primary purpose of stimulating development of the state's resources, whereby the taxable property being increased the tax rate may be decreased. Incidentally full advantage should be taken of the opportunity to make the work of benefit educationally and to realize all other indirect benefits possible.

Intelligent exploitation can only follow intelligent exploration, and since private initiative may usually be relied upon for the one, the state survey may well make the other its own main duty. Exploration, in the generally accepted sense of travel through wild and uninhabited districts, nowadays seldom falls to the lot of the state geologist. By a paradox it is only the more settled and richer states that feel able to afford geological surveys. Exploration, however, may properly be used to cover the whole range of field investigation and we may even include a certain amount of laboratory research without doing violence to the term. In general exploration should be directed to the determination of, *a* the distribution, *b* the mode of occurrence, *c* the value, of each of the mineral resources of the state. Studies of distribution should be not only geographical but geological. It is as important to know in what particular strata to look for a given ore as in what county, and it is in the geological investigation that the special knowledge of the officers of the survey is most useful. The investigation of the mode of occurrence is necessarily a broad one calling for a careful study of the stratig-

raphy and geological history of the district. The purpose of this investigation is to develop rules for prospecting and developing in each instance, and this purpose should be kept steadily in view in order that the whole results may be focused upon it. Studies of the value of the deposit are in part scientific and in part commercial. The genesis must be understood so as to intelligently estimate the probability of extensions and of continuance with depth of an ore body. It is very important to know in the case of a coal outcrop whether it is an isolated pocket or the edge of a large body. Not less important, however, are relations to transportation, ease of stripping or mining, quality as compared with competing material, cost of production, extent of market, and other matters of commercial and economic importance. There is a wide range of opinion as to how far the state survey should go in the investigation of problems of this sort, and probably no hard and fast rule can be laid down. There are none-the-less certain principles to be kept in mind. One of these is to avoid duplication of work. So much is to be done and the funds are usually so limited that there is rarely any justification for taking up work already provided for. The main duty of the survey is to gather and disseminate information not otherwise accessible, but since the people within a state come to look to their own survey for a wide range of information it may properly republish or arrange for joint publication of information collected by other agencies, carefully preparing it for the particular purpose and audience to be reached. In the second place all such information must be authoritative. There are many excellent geologists who are not prepared to give opinions of value on these subjects and in such cases recourse should be had to experts called in for temporary service. One inaccurate or misleading report discredits a whole series of excellent volumes.

With these principles in mind the content of the reports themselves may be briefly discussed. The form and style of publication is generally fixed by law, but where it is left to the option of the state geologist, the dual character of the work would seem to be best met by the publication of bulletins or advance reports dealing with particular subjects or districts, followed by care-

fully planned and maturely developed systematic reports by large districts, by geologic systems, or designed to meet particular needs, such as a hand-book of the geology of the state for the use of schools.

There are particular phases of the work which demand especial notice.

If it is at all practicable without duplication of work statistics of production should be regularly collected and published. No one thing brings the survey into as close relations with producers and makes more for an intelligent interest in the work.

Topographic surveys are usually so expensive and as now carried on are so much more useful for engineering and general purposes than for geologic work that it is a question whether a state survey had not better let them entirely alone. They are valuable enough to find support independently and strictly on their own merits.

Many of the older state surveys went shipwreck by attempting to carry too heavy a load of fossils and it would seem proper that paleontology as such should be left to the museums and colleges. Paleontology as an aid to stratigraphy should be strongly supported and constantly used and a reasonable amount of descriptive paleontology may properly be published as a portion of the description of a formation. Under present conditions, however, and in the light of the past it is a question whether a state survey is warranted in undertaking the investigation of purely paleontologic problems and the publication of paleontologic monographs.

In general it should be remembered that money is given a survey for the application of science rather than for research, though this is not usually interpreted in any narrow or mean sense. The acceptance of the money, however, implies a contract to be faithfully fulfilled and to divert to purposes of scientific research, however important, funds appropriated for the development of natural resources is not only unwise and destructive to the life and usefulness of a survey, but malfeasance of office and should be condemned as such.

H. F. Bain.

Sir:—The history of state organizations for geological research indicates a unity of purpose in their original conception but often a very wide deviation from that purpose in execution. Almost without exception state surveys have been organized by virtue of an appeal to or from the people for the scientific exploitation of their mineral resources. As a motive for organization this is entirely natural and proper and as it is a paramount consideration in organization should also be in administration and execution.

Experience, however, I think, fully justifies the statement that state reports on mineral resources, or generally speaking, on industrial geology, have hitherto been in very large measure of immediate value only, that is, in a definite sense they lack permanence of value. When a geological survey is organized for a definite period or to cover a specified field of work and terminates with the rendering of a final report there is no uncertainty that accounts of mineral resources soon lose their value and must eventually become stale and unprofitable. Such statements of actual and possible economic developments must be kept fresh and keep pace with or precede the commercial demand; hence a state survey with the exploitation of economic resources as its chief cause of being, if efficiently administered, should never be terminated.

In actual practice and at the present time the functions of state surveys and hence of state geologists differ widely. Some are seeking industrial development only, others under the protection of economic investigation are developing distinctively geologic problems; several are openly liberal in scope and prosecute investigations in every direction that may be properly contributory to geology, and some again are simply bureaus of information surviving from former organized surveys.

As then to what a state geologist should include in his reports must be determined by the scope of his activities or the historical development of his organization. I can speak only for New York with reference to the evolution of this problem.

New York has had a geological organization for seventy years. Its geological survey is one of the older of the state departments.

Its early reports ran little to economic geology but rather to structural geology and stratigraphy, then for a long period to none of these, paleontology sweeping all else before it. Twenty years ago its annual reports again began to include treatises on economic geology and stratigraphy and all the work done, save in part in paleontology, was incorporated in these reports. They grew fatter and more fat until they reached a size cumbersome and unseemly.

This method of presenting annually the results of geological research in New York has now been abandoned. General and special problems, whether of economic, stratigraphic, paleontologic, areal or surficial geology are now separately treated each in a bulletin or memoir by itself. The report of the state geologist carries no scientific papers, but presents a general review and summation of the year's work with suggestions for future development. This method proves entirely satisfactory. It not only gives the public in brief the operations of the organization with explicit directions as to where more detailed information on specific problems is to be found but it involves a vast saving of labor and of valuable time to the chief official by holding authors responsible for the editing of their own special reports subject to the rules of the office.

J. M. CLARKE.

Sir:—I appreciate the opportunity to present in ECONOMIC GEOLOGY my views as to the character of publications which a state geological survey should adopt. This subject was given careful consideration in 1896 when the Maryland Geological Survey was organized. Impressed with the unsatisfactory nature of state survey publications generally, I felt that a new survey unhampered by traditions and with adequate funds might perhaps set a new standard for such work. An attempt was made to devise a scheme possessing sufficient elasticity to meet all the possible future requirements of a state geological survey. The working out of this plan during the past ten years has satisfactorily met the requirements for Maryland. I accordingly present the methods pursued by the Maryland Geological Survey as possibly applicable in part at least in some other states.

No two state geological surveys can probably be developed along exactly the same lines and what seemed wise for Maryland may not apply in all particulars elsewhere. Whether the state survey shall confine its investigations to geology and allied subjects alone or whether other and more remote subjects of inquiry shall likewise be included depends upon the provision which the state has already made or contemplates making in such matters. Few states, unfortunately, have any clearly defined policy regarding the subjects to be submitted to scientific inquiry and each state geologist, if he has the confidence of his board, and he is of little use if he has not, is commonly left to develop his own plans. It is, therefore, important that care should be exercised in drafting the legislation desired. Sufficient leeway should be provided in the Act to meet later contingencies, as frequent demands for legislation are most undesirable.

The great majority of our states possess few bureaus which can be classed as scientific, and each bureau feels the necessity of pursuing a number of independent lines of work. The state geologist, for example, finds many subjects more or less remotely related to geology that can be taken up with little additional cost, some of which can be pursued in conjunction with the other work. It becomes necessary, therefore, for the state geologist to select carefully those subjects which can be advantageously followed with due regard to the needs of the state and the efficiency of the state geological survey itself.

SUBJECTS THAT MAY PROPERLY BE TAKEN UP BY A STATE GEOLOGICAL SURVEY.

Topography.—The state geological survey must of course put the geological work in the first place in its plans, but it is evident that little of a permanent nature can be accomplished until topographic maps have been prepared. Experience in this country has clearly demonstrated that the preparation of these maps can be best and most economically secured by co-operation with the U. S. Geological Survey. In most states the state geological survey must assume the responsibility for seeing that this work is done and this is often a great drain on its funds, unless a special appro-

priation is made for the purpose, as has been done in Maryland. In this connection it must be recognized that little, if any, topographic work would be carried on by the U. S. Geological Survey if the state itself did not contribute.

Descriptive Geology.—With the topographic base under way areal mapping of the geological formations may proceed, the results being published either on the usual 15′ or 30′ sheets, or on the same base in the form of county maps. The latter have advantages in the south especially, where the county is the chief political unit and where there exists a strong local demand for a county map. As the people of the state meet the expenses of the work there is much gained and little lost in adopting the county as the unit. The text of the descriptive geology may in such a case form a part, generally the chief part, of the county report.

Systematic Geology.—Contemporaneously with the areal mapping should go the systematic study of the formations of each geological period and this means an exhaustive investigation of the stratigraphy, lithology and paleontology of the rocks throughout the state and as far beyond as feasible. Such a series of systematic reports will prove, if properly carried out, one of the most lasting results of the survey's work. Two such reports have already been published by the Maryland survey and eight more volumes are contemplated.

Economic Geology.—A thorough investigation of the products of economic value should accompany the other work and where necessary a specially trained expert should be secured. For practical purposes the results of such investigation should not only be published with the descriptive geology but should also be brought together in separate reports where they will be readily available to the mining geologist and the investor. In Maryland the economic geology of each county thus far studied has been discussed at length in a special chapter and the three leading mineral products of the state—coal, clay and building-stones, have also been exhaustively treated in special reports by experts.

Physiography.—The topographic features of the state need interpretation in the light of the stratigraphy and structure, and

should form an important phase of the work of the state geological survey. There is almost no subject that the local organization can take up which can be so advantageously utilized for educational purposes and in elementary form render the survey an important adjunct to the Department of Public Instruction.

Agricultural Soils.—Following the geological work, or better, in conjunction with it, a survey of the agricultural soils may be made, a practical form of investigation which can now be carried on by each state in co-operation with the U. S. Bureau of Soils. This information appeals strongly to the agricultural interests and proves of much value in advertising the farming lands of the state.

Terrestrial Magnetism.—The study of terrestrial magnetism can be readily carried on by a state geological survey in co-operation with the U. S. Coast and Geodetic Survey. In Maryland north and south lines have been established at every county seat as the result of the most detailed magnetic survey thus far conducted in this country. Tables of magnetic variation dating back to early in the eighteenth century for use in determining property lines have been furnished the authorities and published in the county reports.

Forestry.—The distribution of the forests of the state may be mapped on the same topographic base as the geology and soils through cooperation with the U. S. Forest Service. The chapter on the forest growth included in each county report has found much favor with the lumbering interests.

Hydrography and Climate.—Studies of the hydrography and climate may also be carried on, the former through the U. S. Geological Survey and the latter through the U. S. Weather Bureau in co-operation with the State Weather Service, and the data thus secured admirably supplement the results of the other lines of work. Chapters on these subjects have been incorporated in the Maryland county reports. To these might be added, if it is thought desirable, studies of the *Flora* and *Fauna* as has been successfully done by some of the state surveys.

The subjects enumerated above comprise what may be termed the *physical features* of a country, although only in exceptional

cases would they all fall within the province of the state geological survey. In Maryland, however, and in many of the other smaller states, when no provision has been made for the investigation of these questions, the state geological survey is the only state bureau that is properly equipped to consider them. It can thus render an important public service by taking up such as can be advantageously administered without injury to the primary work for which the survey was organized.

There are still other subjects that may well be entrusted to a state geological survey. Among these may be mentioned state highway engineering, state mineral exhibits and boundary surveys.

Highway Engineering.—There is no state bureau that can so largely influence the great problem of state highway construction and, under favorable conditions, assume the direction of it, as the state geological survey. In Maryland this work, which began eight years ago in the study of road-building materials, has passed through various stages until the state geological survey now has control of the building of the state highways under an act appropriating $200,000 annually to be met by a similar amount from the counties, making a total of $400,000 annually devoted to this purpose. With this is associated a state laboratory where materials for city streets and public buildings are tested, many new methods having been devised by the well-trained engineer in charge. The results of this work have formed the basis of several valuable reports which constitute a part of the state geological survey publications.

State Mineral Exhibits.—The state geological survey is better qualified than any other state agency to undertake the work of displaying the mineral resources of the state at expositions. Special publications setting forth the salient features of the mineral wealth can be advantageously prepared by the state survey and distributed at such times so as to advertise the economic possibilities of the state. The exhibit should be organized in a manner to show the natural materials and the manufactured products made from them, and the state survey understands this relationship as no other organization can. The Maryland survey has been charged with this duty at the Buffalo, Charleston and

St. Louis expositions, and the results have proved eminently satisfactory to the state.

Boundary Surveys.—In the absence of a state engineer the state geological survey can render a distinct service in acting for the state in the determination of state, county and township boundaries, particularly in our eastern states where the monuments are in many instances destroyed and questions relating to property lines and taxation are often before the courts. The Maryland survey has acted on several occasions in this capacity and the reports published have had a practical as well as an historical interest.

METHODS OF PUBLICATION THAT MAY BE ADOPTED BY A STATE GEOLOGICAL SURVEY.

The methods of publication that may be adopted by a state geological survey will necessarily differ according to the requirements in each case. We have found it desirable in Maryland to adopt three series of reports.

First. Volumes I., II., III., etc., in which special articles are published, more particularly those of general interest to the public. In this series are included the economic reports on the coals, clays and building stones, the reports on highway construction and testing, the reports on boundary surveys and terrestrial magnetism, and the general articles of educational value. These reports, especially those on economic subjects, are also issued separately. A larger edition of this series is published than of the others.

Second. County Reports and Maps which contain a detailed discussion of the local features and are of value mainly to those seeking information regarding a special district. These reports contain chapters on physiography, geology, mineral resources, agricultural soils, terrestrial magnetism, forestry, hydrography and climate. Accompanying each report is a folio of topographic, geologic, soil and forestry maps on the scale of one mile to the inch, this case being bound in cloth of the same size and style as the text. In this form the folio case becomes as permanent as the volume.

Third. Systematic Geology and Paleontology, containing a detailed discussion of the stratigraphy, lithology and paleontology of the formations of each period. As nearly every period of geological history is represented in Maryland this series when completed will contain ten volumes. Two volumes have already appeared treating of the Eocene and the Miocene. It is planned to figure and describe, as far as possible, every species of organic remains represented in the rocks. It is felt that these reports should be in as large a degree as possible educational, and only by giving the average student of Maryland geology, especially if he be a teacher of natural science in the public schools of the state, an exhaustive and systematic treatise, can he get an adequate idea of the geological conditions. These reports are sent only to libraries and to special students of geology.

If all the volumes of a state geological survey appear in a numbered series the book collector will never be satisfied until he has everything. This causes an unnecessary drain on the expensive systematic volumes which can with advantage be placed only in libraries and with students of geology.

THINGS TO BE AVOIDED BY A STATE GEOLOGICAL SURVEY.

Lack of System in Treatment and Publication.—It is highly important for the non-scientific reader, not to mention the geologist, that some systematic method of treatment and publication should be followed. The relative values of the various subjects discussed may be readily obscured if part of the subject is discussed at great length at one point and only briefly or in a different form at another in the same series of reports. A change in style and size in the same series is also most confusing. Such a lack of system has been too often apparent in state geological survey reports.

Reports of Progress that Contain Only Provisional Views.—Reports of progress often contain only undigested field notes of little general value, the local generalizations introduced being liable to modification with further field study. It would be far better to wait until the work is completed and a final statement can be made. Even with the greatest care new evidence is con-

stantly appearing which changes former conceptions, but it is unnecessary to lead the reader through all the stages that the mind of the critical geologist may pass in his studies. Oftentimes the state geologist is not at fault, his judgment being overruled by legislative demands or by an order of his board.

Failure to Interpret the Economic Possibilities of the Mineral Deposits.—It is important that the state geological survey should regard the economic possibilities of each region surveyed and if necessary secure a specially trained expert to examine those mineral deposits regarding which there is any doubt or which demand particular treatment. Not every geologist can recognize the value of a mineral vein or of a clay bed. Frequently in the past state geological surveys have ignored these and other commercial features altogether, to the ultimate discredit of the work by the people of the state who have a right to demand a thorough study of this phase of the subject. A state geological survey can be made a great factor in the state's industrial progress and the survey that ignores economic work needs thorough reorganization.

Failure to Utilize the Educational Possibilities of Geological Investigation.—Every state geological survey should recognize the great opportunities presented to it of instructing the people of the state regarding the physical features of their own region. An attempt should be made to present every subject in a way that will enable the people to comprehend its value and gain knowledge from it. For the pupils of the schools, maps and articles may be prepared that will serve a valuable purpose in the educational system of the state. There has often been an absolute disregard of this important factor in state geological survey work with an accompanying loss of interest on the part of the people of the state.

Bad typography, Illustrations and Paper.—Too many state geological survey reports are striking examples of bad bookmaking which detracts from the interest which the reports would otherwise arouse. An attractive presentation is the first essential step in winning the attention of the educated layman and means much for the preservation of the published information. There

is little satisfaction to either author or reader in poorly executed volumes with bad typography, illustrations and paper. If possible the volumes should be published by the survey and not left to the judgment of some state printer who is generally selected for political reasons.

RELATIONS OF THE STATE GEOLOGICAL SURVEY TO THE U. S. GEOLOGICAL SURVEY.

There is no occasion for any conflict of interest between the U. S. Geological Survey and the state geological survey. As has been already pointed out the topographic surveying can only be satisfactorily conducted by the state in co-operation with the U. S. Geological Survey, and the same is only in a somewhat less degree true in the case of the geological, hydrographic and statistical work.

The geological work of the state survey can be most advantageously carried on in close association with the Federal Survey, since the geologists of the latter are often in a position to render most valuable advice and assistance in certain phases of the investigations. The state geologists, on the other hand, are often better fitted to deal with purely local questions, and the state bureau can also publish the reports in a form better suited to the state's needs. In Maryland some of our field work and the preparation of some of our reports have been the joint product of the national and state geologists. Not infrequently the state has furnished material for the national geologic folios and other publications. For the past ten years there has been no difficulty in reaching a harmonious basis of work all along the line. Perhaps the most practical question involved from a state's standpoint would be the necessary slowness of national work in a state that appropriated nothing for geological purposes. With the great area of the country as a whole the prospects of a state like Maryland receiving a thorough geological investigation by the U. S. Geological Survey before the close of the century would be remote indeed. The state must therefore maintain a state geological survey if it expects the U. S. Geological Survey to hear its call for help.

The hydrographic studies can also be conducted by the U. S. Geological Survey and the state survey jointly, the former furnishing the instruments and supervision and the latter meeting the expense of the local observers. In return an expert hydrographer from the national bureau can furnish as required the necessary material for the state publications.

The statistical work can be carried on by the state geologist in the double capacity of agent for the U. S. Geological Survey and official representative for the state. The Federal forms and franks result in a great saving to the state bureau, while the U. S. Geological Survey obtains the advantage of an agent with a knowledge of local conditions and personally acquainted with the operators. Furthermore, the operators are not confused and annoyed by similar requests from different sources.

The same advantages are to be derived from national and state association in the co-operative survey of the agricultural soils with the U. S. Bureau of Soils, the forestry with the U. S. Forest Service, the terrestrial magnetism with the U. S. Coast and Geodetic Survey and the climate with the U. S. Weather Bureau.

W. B. CLARK.

HYPOTHESIS TO ACCOUNT FOR THE TRANSFORMATION OF VEGETABLE MATTER INTO THE DIFFERENT GRADES OF COAL.

DISCUSSION OF PAPER BY MARIUS R. CAMPBELL.

Sir:—The recent interesting article by M. R. Campbell[1] on the origin of coal suggests certain comments to me. Mr. Campbell is certainly right in saying that time by itself does nothing. It merely offers opportunity for other factors to work. His suggestion that the ease of escape of the by-products of alteration is one of the dominant factors in determining the rate and extent of alteration of vegetable matter into coal is therefore very plausible. One is tempted to enquire whether the mantling of the great ice sheet should not have checked that action, and whether therefore, according to his hypothesis, the coals north of the Ohio

[1] This Journal Vol. I., No. 1, p. 26.

should not be in an average way less developed than those farther south, where the gases have been less confined and the temperature probably on the whole higher.

Is this really the case?

It occurs to me that there are other factors which may not be negligible. The composition of the vegetable matter of which the coal is made must have varied with the evolution of plant life.

The lack of coal beds in the lowest part of the geological column may be due to the fact that plants then existing decomposed almost entirely into bituminous products.

Again the composition of the water in which the vegetable deposits were laid down must have had some influence on the form and rate of decomposition, even as it does on olives and pickles to-day. May not the effect of the joints to which Campbell refers have been in letting down surface oxidizing waters, as well as in letting the gaseous products of decomposition escape, and may it not have been the access of such waters, rather than heat, which has determined the rate and extent of the development of the coal toward anthracite.

A. C. LANE.

REVIEWS.

Tin Deposits of the World. By Sidney Fawns. Pp. xii + 237, 56 figures and plates, containing a bibliography of 53 articles. Published by *The Mining Journal*. London, 1905.

In his preface Mr. Fawns says: "The literature of tin mining is at present in a scattered condition. It is the object of the author to produce a collected account of the tin deposits and methods of tin mining in various parts of the world which will be of some practical value to the tin miner and investor."

The author's first statement is eminently true, and in his second must rest his justification for publishing a volume, the inaccuracies of which seriously impair its scientific value.

All errors of the book, however, are possibly not upon the author's head, many of them being due to wretched proof-reading. As examples of the inaccuracies of the book may be mentioned: page 2, speaking of cassiterite, he remarks that the "crystals occur in squares" and that "under the microscope . . . the purest crystals are dark with polarized light." Cassiterite is tetragonal and not isometric as these remarks would indicate. On pp. 14–15 he gives five examples of alluvial tin deposits to show that they average one foot of pay gravel to four feet of barren gravel, or 1:4; these examples give the ratios 12:37, 1:3, 2:7, 1:4, 8:17, as the figures are stated. Colloquialisms and provincial terms occur through the book either with no explanation or one that follows late. On p. 20 he gives figures to show the cost of mining alluvial gravels in the Malay States in both dollars and pounds sterling without stating what "dollar" is used. It is probably the Mexican dollar, as his figures are about twice too large for the American unit. On p. 47 *et sequi* he refers to "sluice-heads" as a measure of the volume of water but nowhere defines the term. On p. 158 he states that only 291 14/100 pounds of tin were produced at the Temescal mines in southern California. As a matter

of fact, 269,000 pounds were produced.[1] Numbers of such cases could be cited. The proof-reading makes Humbolt appear as "Hennbolt" (p. 155), Nevius as "Nerius" (p. 156), and so on through a long list.

In the course of compilation various works have been drawn on liberally without credit, and where it is given quotation marks are often omitted, so that to one unfamiliar with the literature it can not be told how much is taken from a particular article—a thing unjust to the original author and provoking to one who cares for the sources of information. Thus the article upon Siam is identical with that published by the Siamese Commission for the Louisiana Purchase Exposition, 1904, in their book "Siam," pp. 241–242, and a good deal of the first part of the article on Mexico is evidently taken from W. R. Ingalls' "The Tin Deposits of Durango, Mexico,"[2] but no credit is given in either case.

The bibliographic references are often incomplete and occasionally incorrect, and plates and figures are copied without credit. Thus, the illustration opposite p. 30 of "Alluvial Tin Mining in the Malay Peninsula"[3] is from Becher's "Mining in the Malay Peninsula," the map of the York Region, Alaska, is from Bulletin 299, U. S. Geological Survey, and so on with both figures and plates.

The generalizations on geology, classification of deposits, etc., are not particularly strong and the arrangement does not seem very logical, one country following another without apparent plan.

There are, however, good parts to the book. The historical article is good, and he gives interesting figures on the effectiveness of coolie labor in Banca, Billiton and Sumatra, where men, working for a rate nominally of $2.50 (and board?) per month, but netting them about $1, move an average per year of from 10,600 to 14,000 cubic yards per man, working eight-hour shifts. Elsewhere in Malaya a seven-hour day is often worked. Such figures have a large bearing on the length of the labor-day now

[1] Benedict, W. DeL., Tin. In *The Mineral Industry for 1892,* N. Y., 1893, p. 453.

[2] *Trans. A. I. M. E.,* Vol. XXV., 1896, pp. 146–163.

[3] *Trans. Inst. Min. and Met.,* London, Vol. 1, 1892–1893, pp. 78–107.

being discussed in connection with the building of the Panama Canal in a, presumably, similar climate.

His description of mining conditions on the Malay Peninsula is also good and he quotes some little-known literature on very interesting phases of the New South Wales tin deposits. He also gives a good description of the operations at the Briseis mine of Tasmania. At the latter place deep gravels under lava of considerable thickness are being worked successfully.

On Cornwall he has summed up conditions very well, and his conclusion that there is a paying future, under present prices, for some of the closed tin mines is interesting. Concerning northern Nigeria, he has obtained a good article from R. C. Nicolaus who describes a strange occurrence of native tin in pieces "the size of beans," coated with a film of cassiterite and lying beneath fifteen feet of gravel.

The article on tin dressing, a large part of which was contributed by Fraser & Chalmers, is quite full and good, but a better description of some of the machines would be desirable. The article on tin assaying is also good, but by no means complete.

To persons out of reach of original tin literature the book will undoubtedly be of some value.

F. L. HESS.

Report on the Coals of Maryland. By WILLIAM BULLOCK CLARK, with the collaboration of GEORGE C. MARTIN, J. J. RUTLEDGE, B. S. RANDOLPH, N. ALLEN STOCKTON, W. B. D. PENNIMAN, and ARTHUR BROWNE. Part of Vol. 5, Maryland Geological Survey, pp. xv + 430, with 23 plates and 37 figures.

The Geological Survey of Maryland has just issued a report on the coals of the state as a part of Volume V. of its regular series of publications. The part devoted to coal is also published separately, making a handsome volume of 430 pages, with many maps, sections, and half-tones gotten up in the usual elaborate style of the Survey.

The report, as stated in the preface, is the result of many years investigation of the coal deposits of western Maryland, and presumably is a sort of summary of previous publications that treat

of counties in detail. Evidently the report is intended to be the hand compendium of the coal operator and prospector, and it is extremely unfortunate that it has not been condensed into a volume more easily handled, and one that can be taken into the field. Apparently it has been prepared without any thought of condensation, but rather with the idea of making the most of the material presented. This is well illustrated by the printing of a single coal section, or a single line of sections on a page, when in almost all cases two could be placed side by side without detriment to the appearance of the report. By actual measure the sections, if placed end to end, without any allowance for headings, would cover 127 pages, and if two were placed side by side, there would be a saving of at least 63 pages of the report.

The first chapter is devoted to the origin, distribution and use of coal. The author seems to have felt compelled to begin at the earliest known use of coal in the world, but what this has to do with the development of the Maryland coal field is not stated. This might well be omitted from the volume, as it adds little or nothing to its value, and its omission would reduce the report to a more convenient size.

This chapter is illustrated with maps giving the distribution of the coal fields of the United States, as well as a map on a somewhat larger scale of the northern Appalachian coal field. Such maps are very convenient for reference, but the tints which are used to represent the coal fields are so light that these areas are scarcely recognizable instead of being the most prominent feature of the maps.

The discussion of the character of the coal is a fairly good abstract statement, but the classification given on page 239 is confusing, since it differs decidedly from the Pennsylvania system as first proposed by Persifor Frazer without giving the reason for the change. The fuel ratios in the Pennsylvania system are as follows: Hard, dry anthracite, 100 to 12; semi-anthracite, 12 to 9; semi-bituminous, 8 to 5; and bituminous, 5 to 1. In the Maryland report the fuel ratio of anthracite is given as ranging from 28 to 5; semi-bituminous coal from 5 to 3; and bituminous 3 to 1. The present writer does not question the statement that these

figures represent the conditions in Maryland better than the Pennsylvania scale, but the use of different limiting ratios for the various groups of coal in different states deprives the system of what value it might have as a standard of classification for the highly carbonized coals of the country.

The purely geologic part of the report is much more thorough and satisfactory than the parts dealing with other phases of the subject. It is divided into several sections. The chapter on the geology of the Maryland coal district is a very clear and concise statement of the general geologic relations of the coal field, together with a brief account of what are supposed to have been the geographic conditions during each epoch of deposition. In general this is well presented, but the author does not seem to appreciate the importance of the great time and erosion break in the early stages of the Pottsville, nor does he seem to understand that this has passed the hypothetical stage and that it has been unquestionably demonstrated throughout the entire western side and over most of the central part of the Appalachian coal basin.

The part dealing with the correlation of formations and members shows the painstaking work of the authors in the careful study they have given to the minute details of stratigraphy, and the keen discrimination manifest in their correlations. It is interesting to note how large a part the study of fossil plants made by Mr. David White has played in these correlations, for the present writer can look back only a few years and recall a time when such evidence was met with nothing but sneers and derision. This able exponent of paleozoic botany has compelled recognition, and has shown that Carboniferous plants, when rightly interpreted, are thoroughly reliable for stratigraphic and correlation purposes.

The only adverse criticism to be made of this chapter is that the authors have made such definite correlations and have expressed their opinions so forcibly that the reader is almost compelled to accept the conclusion that the striking characteristics of coal beds are their regularity and persistence, and that each indi-

vidual bed of the Pennsylvania series is present everywhere throughout Maryland and can be recognized with certainty wherever found. Perhaps the coal seams of Maryland are the types of regularity, but if so they are certainly exceptional.

The principal chapter from an economic standpoint is the one on the distribution and character of the coal beds. In this there is little to criticise and much to commend. More than 330 graphic sections give the reader an excellent idea of the thickness and character of the coal beds, and the numerous half-tones show also to a certain extent the development of the field.

A very commendable feature is a series of maps showing the areal distribution of the most important coal beds, but unfortunately, with the exception of the Pittsburg coal bed in the George's Creek basin, the maps are on such a small scale that they can not be used in a practical manner. In fact, the greatest defect of the report is the lack of large scale maps on which the facts given in the report may be expressed for the use of the practical man. It is probably assumed that an interested party will refer to the Allegheny or Garrett County reports, but such a report as the one in hand dealing with economic resources should be reasonably complete in itself, and have such maps as illustrate the material in hand without reference to other volumes.

The chapter devoted to the history of coal mining in Maryland is extremely interesting. Such information as this is rarely assembled, and as a consequence it is soon lost to view. Too frequently such material seems to be regarded as beyond the province of a geological survey report, but certainly this can not be true, for the future of a mining industry is judged largely by the past, and it is important to know under what conditions the industry has developed.

The next chapter deals also with a subject that is rarely treated in such reports. It is devoted exclusively to methods of mining and of handling coal at the mines. It is written by a practical engineer in simple language, and from it any person of ordinary intelligence can gain a good idea of methods of mining, and of the arrangement of the outside parts of the mines, including tip-

ple, trackage, screens, et cetera. The chief feature of this chapter is that many of the items mentioned above are illustrated by diagrams which give the essential facts better than any amount of verbal description. This enables operators and engineers readily to compare plans and to see where improvements in existing equipment can be made, or in planning new work to arrange it so as to involve the least possible amount of hand labor, and at the same time be efficient in all respects.

The chapter on the chemical properties of Maryland coals is perhaps the least satisfactory one in the report. Some 250 proximate analyses were made, and probably some ultimate analyses, as these are mentioned in several places, but no results are given. Evidently the chemical work was done with the idea of determining variations in the character of the coal of the different beds; of the same bed in different parts of the field or basin; and of the different benches of the same bed. The last seems to have been quite successful, as the coal from various benches of some of the beds is shown to differ materially in composition. The report states that the analyses show no geographic variations except locally, and that "all the coals in Maryland of commercial value are *semi-bituminous,*" and the reader is led to infer that the chemical composition of the coals in the various basins is practically the same. This statement appears to be misleading, as the tables show a fairly regular decrease in fuel ratios from east to west. The variation is readily seen by computing the fuel ratios of the various analyses. The average fuel ratios of all the analyses of coals in the George's Creek basin is 3.8, in the Potomac basin 3.8, Castleman basin 2.9, and Upper and Lower Youghiogheny basins 2.5. The coals west of the George's Creek and Potomac basins are therefore by *any* classification *bituminous* and not *semi-bituminous.* George's Creek and Potomac, although considered as different basins by the trade, are in reality one synclinal trough and the coals are practically the same throughout. Castleman basin lies next to the west, and the Youghiogheny basin in the extreme western part of the state. There is, therefore, a regular gradation in composition from east to west which

is exactly in line with the conditions that prevail in the Pennsylvania field, as shown in Report M_2 of the Second Geological Survey of that state.

The samples for chemical analysis were all taken in the mines, and, as stated, were intended to represent commercial coal. It is unfortunate that some check samples were not taken of coal after it was loaded on the railroad cars to see how well these mine samples agree with the coal that is sent to market. The present writer's experience has been that mine sampling usually shows better results than actual mining, and therefore that analyses of mine samples are of little value unless the sulphur and ash are multiplied by certain coefficients which should be determined for each field. In general, the writer has found that 1.03 is a fair coefficient for sulphur and 1.3 for ash.

Although attention has been called to many points in which the work could be improved, the present writer wishes to express his high appreciation of the report as a whole and to commend to other state surveys the broad scope of work and the character of reports made by the Maryland Survey.

In this connection it seems desirable to point out certain lines of work on coals that, in the estimation of the present writer, should be undertaken by state organizations. In the report in question the great problems of commercial conditions, and the improvement of the products of the mines have not even been mentioned. These are large fields and they will afford ample returns for investigation. In the close competition which marks commercial conditions at the present time, the loss of revenue due to a heavy percentage of fine coal and to waste products is one of the most troublesome questions that an operator is compelled to face, and any improvement in the utilization of these products either in the improvement of the quality of the coal by washing or otherwise, or by a better method of utilization, like the manufacture of producer gas, are questions that are well worthy the attention of a state geological survey. One of the legitimate functions of such an organization is to study such difficulties and to point out remedies; in other words, to carry on a campaign of education, teaching the operators how to effect a

greater saving on low-grade or waste products, and teach the public that such improvements are possible, and would be made if the people were united in demanding better fuel.

It is to be hoped that this report will be followed by others dealing with these phases of the subject, and that other state geologists will give the matter like attention.

M. R. CAMPBELL.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

F. H. MOFFIT AND D. W. OHERN.

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SCIENTIFIC NOTES AND NEWS[1]

AT THE CLOSE of last season, Dr. A. E. Barlow of the Geological Survey of Canada was sent to British Columbia by the Dominion government to make investigations into the zinc resources of that province.

Dr. Barlow's investigations have been carried out in connection with the work of a commission which has recently been appointed by the Dominion government, and whose work has been actuated by the fact that the lead-silver deposits of East and West Kootenay have been developing an increased content of zinc as the workings have been carried to greater depth. A report of this commission by Mr. Ingalls of New York will appear shortly and Dr. Barlow's report will appear in connection with it.

In addition to investigating the zinc resources of British Columbia the commission is also investigating the problem of the best methods of separating the zinc blend from the galena in these ores.

DURING THE PAST YEAR Professor R. W. Brock and Dr. G. A. Young of the Geological Survey of Canada have been engaged in the construction of a structural map of the Rossland district. As a basis for this work a detailed contour map of this district on a scale four hundred feet to the inch, is now nearly completed and will serve as a basis on which to show geological structure of this important mining camp. The underground geology will also be represented in sections.

This map will not only be of great value to the several mining companies operating in the Rossland district, but will also be of great interest to those interested in economic geology from a

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such scientific and personal items as may come to their notice.

scientific standpoint as bearing upon questions dealing with the origin of the ores.

DR. A. E. BARLOW of the Geological Survey of Canada is now completing a map of the district lying immediately to the south and southwest of the Cobalt district of Ontario, to which so much attention has recently been directed. In this district rocks, both Keewatin and Huronian age, have been recognized, as well as very numerous intrusives. A vein containing Cobalt ores has already been located at Rabbitt Lake in this area. Dr. Barlow's geological map on a scale of one mile to the inch will be of great value to the prospectors who are intending to enter this district during the coming summer.

R. G. MCCONNELL has recently published a report on the geology and economic resources of the Windy Arm of Tagish Lake, Yukon Territory.

THE COBALT DISTRICT of Ontario, to which reference has already been made, has, it is believed, reached a total yield of two and one-half million dollars. It has now seventeen producing mines, the many carloads of ore each having a value of from $60,000 to $80,000 have been shipped from this district, while one carload valued at $100,000 has recently been sent out on the Temiskaming and Northern Railway which traverses this district.

THE GEOLOGICAL SURVEY of Victoria is paying particular attention to the relations which exist between the quartz veins and the shoots of gold that occur in them, also to the relations between the lodes and their containing rocks whether sedimentary or igneous.

In the sedimentary rocks it is recognized that certain zones are productive of gold while other zones are barren. The structure of the sedimentary rocks is therefore being studied and it is intended by means of the organic remains to eventually locate both the productive and barren zones. But besides the original alternations of barren and productive beds in these formations other conditions have to be studied, such as the manner in which the once horizontal beds are now bent into a series of anticlinal and synclinal folds. Still further to complicate matters these

beds have been subjected to faulting of several kinds and then denuding influences have tended to obliterate all preceding influences. The unraveling of these problems in so far as the auriferous veins are concerned is being attended to.

The relations between the auriferous reefs and the containing beds as to their conformability to the beds or their intersection of the beds; the influence of the beds in determining the direction of the auriferous shoots and the enrichment of the lodes at certain intersections with the country rock; the effects of local enrichment of the lodes when first formed and of secondary enrichment near the surface are being studied and an endeavor is being made to apply the results of such research to practical mining operations. The work of the survey as relating to auriferous lodes is briefly indicated above. Gold being our chief mineral product, especial attention is directed towards elucidating its diverse methods of occurrence.

E. J. DUNN, *Director.*

GEOLOGICAL SURVEY OF VICTORIA,
January 11, 1906.

DURING THE FIELD SEASON of 1905 Mr. H. P. Woodward, assistant on the State Geological Survey of Western Australia, has been engaged in mapping the Menzies district of the North Coolgardie goldfield.

The Menzies district is of considerable interest owing to the fact that it has yielded from its reefs alone close upon half a million ounces of gold since its discovery in 1894. Mining has been very costly in this district owing to the fact that at a short distance below the surface very hard aphanitic diorite is the country rock. Moreover, there is a great scarcity of water.

The richest ore deposits occur in the zone of hydration, where the hard rocks have been changed into serpentine and chlorite schists and the granitic dykes, by which the field is traversed, into sericitic schists.

Mr. Woodward is now engaged upon the preparation of a geological and mining map, which, with a report, will be shortly published as one of the Bulletins of the Geological Survey of Western Australia.

MR. CHAS. G. GIBSON, B.E., of the staff of the Geological Survey of Western Australia, has just returned from several months' field work in the Mount Margaret goldfield. During the field season of 1905 this gentleman mapped in more or less detail the mining centers of Laverton, Burtville, Erlistoun, Duketon and Mulga Queen, and in addition made a geological reconnaissance through the Cosmo Newberry ranges and from thence to Mounts Warren and Lake Wells.

This officer's report and maps are awaited with considerable interest in that they deal with a portion of Western Australia which up to the present has been, in a geological sense, a terra incognita.

THE EIGHTH ANNUAL MEETING of the Canadian Mining Institute was held on March seventh, eighth and ninth of the present year at Chateau Frontenac, Quebec.

At the regular sessions on these dates a number of interesting papers were presented, some of which were discussed in detail. The most important of these from an economic standpoint are listed below.

The Asbestos Region of Quebec, illustrated by lantern. By the President, George R. Smith.

Genetic Relations of Nickel Copper Ores. By C. W. Dickson, Ph.D.

The Ore Deposits and Geology of the Sudbury District. By Hiram M. Hixon.

The Nickel Deposits near Webster, Western North Carolina. By A. E. Barlow, Ph.D.

The Atikokan Nickeliferous Pyrrhotite Deposits and Their Origin. By F. Hille.

The Chibogamoo Mining Region. By A. P. Low.

Notes sur un Dépot de Pyrrhotine Nickelifere sur une pointe appellée, "Malachite Point." By A. Muscovici.

Rare Earths in the Pegmatite Veins of our Laurentian Range. By J. Obalski.

Probabilité de touver des Mines au Nord de la Province de Québec. By J. Obalski.

Canadian Chromic Iron Ores. By F. Cirkel.

Canadian Graphite. By H. P. Brumell.

Recent Development at Cobalt. By W. G. Miller.

The Windy Arm Mining District. By R. G. McConnell.

Notes on the Utilization of Poorer Grades of Coal Slack. By D. B. Dowling.

Lost Packer Mine, Lone Creek, Idaho. By E. P. Jennings.

On Some of the Natural Resources of the Peace River and Athabaska Regions. By Alfred Von Hammerstein.

On the Possibilities of Steel Manufacture in British Columbia. By Wm. Blakemore.

The Colliery Manager. By W. D. L. Hardie.

Some Observations Relative to the Occurrence of Deposits of Copper Ore on Vancouver Island and Other Portions of the Pacific Coast. By Wm. M. Brewer.

Prospecting in the Torbrook District, N. S. By W. F. C. Parsons.

On the Need of a Topographical Survey of the Dominion of Canada, Particularly with Reference to the Development of the Economic Resources of the Dominion. By Dr. F. D. Adams.

The Education of Mining and Metallurgical Engineers, with Special Reference to Teaching and Practical Work. By Dr. J. B. Porter.

The Influence of Varying Degrees of Superfusion in Magmatic Differentiation. By Alfred C. Lane.

The Occurrence of Diamonds in the Drift in Some of the Northern States. By Robert Bell, F.R.S.

The meetings were largely attended and the papers presented, especially those dealing with the new cobalt-nickel region of Chibogamoo, have attracted a wide-spread interest.

Dr. Geo. I. Adams, who has been investigating for the government of Peru the underground water resources of that country, expects to return shortly to the United States.

Mr. W. H. Emmons and Mr. G. H. Garrey, who were engaged with Mr. F. L. Ransome in studies of the Goldfield, Bullfrog and other new mining districts in southern Nevada, have returned to Washington.

MR. F. E. WRIGHT has been elected to one of the Secretaryships of the Geological Society of Washington, vice Geo. Otis Smith, resigned.

MR. J. E. SPURR is at present (April 7th) in Washington preparing a report on the Georgetown District, Colorado, for the U. S. Geological Survey. Mr. Spurr will leave for Mexico in a few days but expects to return to Washington early in May and complete such investigations as he had in hand when he resigned his position on the Survey.

MR. ROBERT W. SAYLES, Harvard, '01, has recently donated $50,000 to that University for the preparation and maintenance of a geological museum.

MR. M. L. FULLER, Chief of the Eastern Section of Hydrology of the U. S. Geological Survey, gave a course of lectures at Chicago University during the first week in April on the "Work of the Hydrographic Branch of the Geological Survey.

MR. HENNEN JENNINGS has returned from South Africa and taken up his permanent residence in Washington, D. C.

ON APRIL 4–5, a civil service examination lasting seven hours each day, for applicants for the positions of assistant geologists and geologic aids on the U. S. Geological Survey, was taken by a number of applicants. It is understood that the policy hereafter in the selection of assistants will be to restrict same to those who have qualified in regular examinations.

MR. ARTHUR J. COLLIER has left Washington to begin fieldwork in the coal districts of Arkansas.

MR. J. A. TAFF has left Washington to begin an investigation of the geology of the coal district of eastern Utah.

THE WESTERN MINING PAPERS unanimously advocate the establishment of a department of mines and mining. The so-called Brooks bill, in which it is proposed to widen the scope of the Geological Survey and incorporate it in the Department of Commerce and Labor, is unanimously opposed by the mining press. It does not seem likely that this bill will pass during the present season.

THROUGH THE EFFORTS of a committee of the Geological Society of America an arrangement has been made by which the governments of Canada, Mexico and the United States are co-operating in the preparation of a geological map of North America, which it is proposed to issue in time for the International Geological Congress to be held in Mexico during September.

MR. R. H. SARGENT, the topographer of the U. S. Geological Survey who accompanied the Carnegie expedition to China in charge of Mr. Bailey Willis in 1903–04 to execute topographic surveys in relation to geologic explorations, will deliver a course of lectures to advanced students at Chicago University for three weeks following the middle of April on the use of topographic mapping in geology.